ECF-200UP1-20-0036
Revision 0

Predicted Migration and Attenuation of the Iodine-129 Plume in the 200-UP-1 Operable Unit using the Plateau to River Groundwater Model Version 8.3 in Support of a Technical Impracticability Evaluation

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000030

CPCCo
Central Plateau Cleanup Company

P.O. Box 1464
Richland, Washington 99352

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S. Tomusiak
INTERA, Inc.

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APPROVED
By Julia Raymer at 12:52 pm, Jun 09, 2022

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ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

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Qualifications Summary

Preparer(s):

Name: Stephanie Tomusiak

Degree, Major, Institution, Year: MS, Geological Sciences, University of Colorado, Boulder, 200

Degree, Major, Institution, Year: BA, Earth/Planetary Sciences, Washington University, 1986

Professional Licenses:

Brief Narrative of Experience: Stephanie Tomusiak has well over a decade of expertise in geology, hydrology focused on analytical and numerical modeling, groundwater flow and transport modeling and inorganic chemistry to a wide-array of hydrogeological investigations, industries and environments. She has applied analytical models, and both finite-difference and finite-element numerical modeling techniques to dewatering systems and environmental impacts in the mining industry; simulated the fate and transport of various contaminants; predicted surface water-groundwater impacts from ongoing or proposed mining operations; and conducted water resource and aquifer characterizations. She has performed capture zone analyses and evaluated remediation systems for effectiveness. Her field experience ranges from conducting soil-gas surveys and oversight of remediation studies, to designing, conducting and evaluating field aquifer tests and fracture mapping. She has routinely run, automated and calibrated MODFLOW models, written model pre- and post-processor FORTRAN programs and evaluated and interpreted MODFLOW model results. She has significant experience in database management, data analysis and visualization using ArcGIS, automating workflows with Python scripts and has taken on projects querying large databases using PostgreSQL.

Checker(s):

ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

Name: Helalur Rashid

Degree, Major, Institution, Year: MS, Civil Engineering, Washington State University, 2010

Degree, Major, Institution, Year: BS, Civil Engineering, Bangladesh University of Engineering &

Professional Licenses: Professional Engineer (Washington)

Brief Narrative of Experience: Helalur Rashid's professional experience encompasses numerical modeling of groundwater in the saturated and unsaturated zones, model calibration, groundwater management, geostatistics analysis, sediment transport, and hydraulic characterization of watersheds. He has applied a wide variety of modeling codes and geographic information system software including MODFLOW, MODFLOW-SURFACT, MT3OMS, MODPATH, PEST, Parallel PEST, STOMP, SWAT, HEC-HMS, ArcGIS, Leapfrog Hydro, Groundwater Vistas, RETC, and TecPlot. Helal has worked primarily on environmental restoration projects for the federal government. He is also skilled in using various laboratory and field instruments such as acoustic Doppler velocimeters, laser distance meters, and viscometers.

Senior Reviewer(s):

Name: Gregory Ruskauff

Degree, Major, Institution, Year: MS, Petroleum Engineering, New Mexico Institute of Mining and

Degree, Major, Institution, Year: BS, Petroleum Engineering, New Mexico Institute of Mining and

Professional Licenses:

Brief Narrative of Experience: Greg Ruskauffs professional experience has focused on the areas of performance assessment of both near-surface and geological radioactive waste repositories, regulatory development, dose assessment for residual contamination of soils and buildings, toxic materials risk assessment, and mixed waste issues. His experience includes performing, planning, and managing site investigations and groundwater modeling on various types of projects. He brings expertise in coordinating teams of technical experts to perform activities necessary for the development of integrated interpretations of complex groundwater systems in order to meet or exceed regulatory-driven requirements. He led the analysis and modeling team for a large federal environmental restoration site, whose primary task was to characterize the complex subsurface environment and evaluate groundwater contamination from historical underground nuclear testing. Under Greg's leadership the activity passed, for the first time, a public peer review required by the regulatory agency advancing the first corrective action unit out of characterization and toward closure. The organizational approach was judged to be so successful that the preparation for the next peer review followed the same pattern. Greg's career has been marked by numerous promotions on important federal projects due to his reliable technical and regulatory leadership skills.

SECTION 2 - Completed by Preparer

Calculation Number: ECF-200UP1-20-0036	Revision Number: 0

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SECTION 3 - Completed by the Responsible Manager

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SECTION 4 - Document Review and Approval

Preparer(s):

Print First and Last Name	Position	Signature	Date
Stephanie Tomusiak	Groundwater Modeler	Stephanie Tomusiak Digitally signed by Stephanie Tomusiak Date: 2022.05.27 12:28:35 -06'00'	

Checker(s):

Print First and Last Name	Position	Signature	Date
Helalur Rashid	Senior Hydrologist	S M Helalur Rashid Digitally signed by S M Helalur Rashid Date: 2022.05.27 11:30:47 -07'00'	

Senior Reviewer(s):

Print First and Last Name	Position	Signature	Date
Gregory Ruskauff	Principal Hydrogeologis	Gregory J Ruskauff Digitally signed by Gregory J Ruskauff DN: cn=Gregory J Ruskauff, o=INTERA Inc., ou, email=gruskauff@intera.com, c=US Date: 2022.05.27 12:23:36 -07'00'	

Responsible Manager(s):

Print First and Last Name	Position	Signature	Date

SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

Prior to Initiating Modeling:

Required training for modelers completed:

Integration Lead: **C Farrow Signed on behalf of Lynette Hale.**

Lynette Hale

Print First and Last Name

CHRISTOPHER FARROW (Affiliate) Digitally signed by CHRISTOPHER FARROW (Affiliate) DN: C=US, O=U.S. Government, OU=Department of Energy, OID.0.9.2342.19200300.100.1.1=89001003727219 + CN=CHRISTOPHER FARROW (Affiliate) Reason: I have reviewed this document Location: your signing location here Date: 2022.06.02 12:06:35-05'00' Foxit PhantomPDF Version: 10.1.7

Signature / Date

Safety Software Approved:

Integration Lead:

Christopher Farrow

Print First and Last Name

CHRISTOPHER FARROW (Affiliate) Digitally signed by CHRISTOPHER FARROW (Affiliate) DN: C=US, O=U.S. Government, OU=Department of Energy, OID.0.9.2342.19200300.100.1.1=89001003727219 + CN=CHRISTOPHER FARROW (Affiliate) Reason: I have reviewed this document Location: your signing location here Date: 2022.06.02 12:07:28-05'00' Foxit PhantomPDF Version: 10.1.7

Signature / Date

Calculation Approved:

Risk/Modeling Integration Manager:

William Nichols

Print First and Last Name

acting for

Gregory J Ruskauff Digitally signed by Gregory J Ruskauff DN: cn=Gregory J Ruskauff, o=INTERA Inc., ou, email=gruskauff@intera.com, c=US Date: 2022.06.02 10:15:57 -07'00'

Signature / Date

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Attachment

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Terms

CIE	cumulative impact evaluation
CPCCo	Central Plateau Cleanup Company
Cmax	maximum concentration
COI	contaminant of interest
CPGWM	Central Plateau groundwater model
CY	calendar year
DOE	U.S. Department of Energy
ECF	environmental calculation file
ERDF	Environmental Restoration Disposal Facility
HISI	Hanford Information System Inventory
IC	initial concentration
K_d	partitioning coefficient
LSQR	least squares regression
MODFLOW	MODular three-dimensional finite difference groundwater FLOW model (software)
MT3DMS	Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems (software)
OU	operable unit
P2R	plateau-to-river (model)
P&T	pump and treat
REDOX	reduction oxidation
Rwie	Ringold Formation member of Wooded Island – unit E
SP	stress period
TI	technical impracticability
95%UCL	95th percent upper confidence limit

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1 Purpose

The purpose of this environmental calculation file (ECF) is to document the effect of ceasing injection pumping for the iodine-129 (I-129) plume and subsequent fate and transport at the 200-UP-1 Groundwater Operable Unit (OU) in the U.S. Department of Energy's (DOE's) Hanford Site to assist in determining a technical impracticability (TI) waiver zone. The 200-UP-1 OU underlies the southern portion of the 200 West Area and vicinity (Figure 1-1). Injection pumping started in October 2015 with three injection wells (299-E11-1, 299-E20-1, and 299-E20-2) located east of the I-129 plume in the 200-UP-1 OU Figure 1-1. Remedial action plan scenarios were evaluated in ECF-200UP1-14-0052, *Local-Scale Simulation of Iodine-129 Plume Containment for the Proposed Injection Wells at the 200-UP-1 Operable Unit* and ECF-200UP1-14-0053, *Containment System for 200-UP-1 Iodine*. The pumping schedule for containment of the leading eastern edge of the plume has a total injection of 150 gal/min distributed evenly among the three injection wells. This calculation uses groundwater flow and transport modeling to evaluate the impacts of ceasing injection under two different time horizons (end of calendar years [CYs] 2020 and 2037) and a detailed evaluation of the evolution of the plume with mean concentration evaluation using the 95th percent upper confidence limit (95%UCL) to assess cleanup during the time of the simulations (2018 through 2617).

This document includes two pumping scenarios that vary I-129 injection well cessation. Scenario 1 models I-129 injection well cessation at the scheduled end of all 200 West Area Pump and Treat (P&T) operations in 2037 utilizing only the 200-UP-1 OU. Scenario 2 differs from Scenario 1 in that the date of I-129 injection well cessation is the end of 2020. An I-129 monitoring network was developed based on the existing I-129 monitoring network and extended to include wells covering the locations along which the I-129 plume transport is expected within 200-UP-1 OU to evaluate 95%UCL I-129 concentration.

The outcome of the flow-and-transport simulations were used to evaluate the impact of I-129 injection operations in terms of 95%UCL mean concentration in the monitoring network, the maximum aerial extent of the modeled plumes, and maximum concentration (Cmax) reported by the model until the cleanup level is reached.

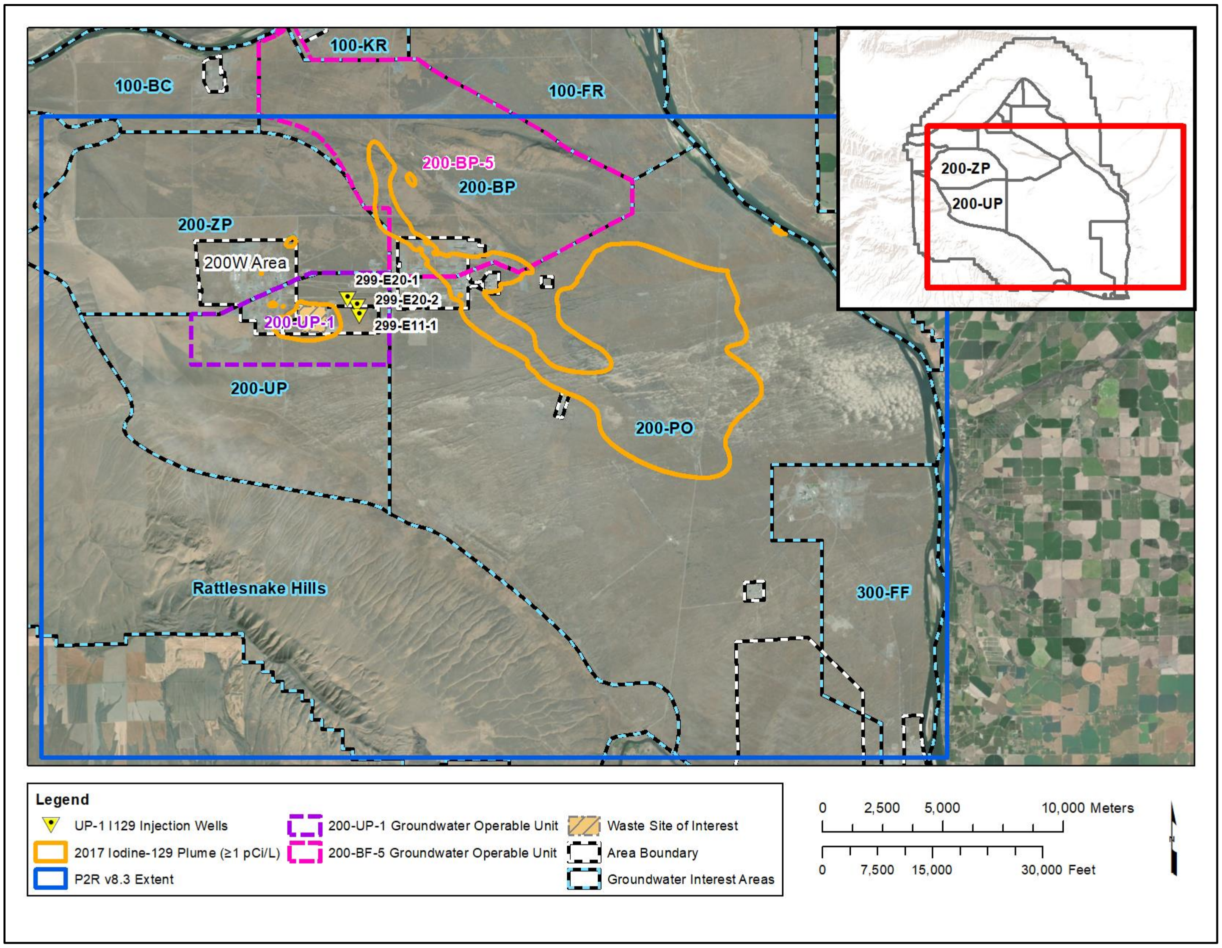

Figure 1-1. I-129 Plumes Originating in the 200-UP-1 and 200-BP-5 OUs, and I-129 Containment Injection Wells (2017)

2 Background

I-129 is one of the contaminants of interest (COIs) identified in DOE/RL-2013-07, *200-UP-1 Groundwater Operable Unit Remedial Design / Remedial Action Work Plan* and EPA et al., 2012, *Record of Decision for Interim Remedial Action Hanford 200 Area Superfund Site 200-UP-1 Operable Unit*.

The I-129 plumes in the 200-UP-1 OU originate from the U Plant and Reduction Oxidation (REDOX) Plant waste sites, with the latter being the primary source DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). I-129 occurs as two plumes, one from the 216-U-1 and 216-U-2 Cribs near U Plant and a second from the REDOX Plant waste sites in the southern portion of the 200 West Area. These plumes merge downgradient and become indistinguishable. ECF-200UP1-14-0052 provides an overview of the evolution of I-129 values at the U Plant and REDOX Plant Sites. Previous I-129 containment analyses (ECF-200-UP1-14-0052 and ECF-200-UP1-14-0053) used a two-dimensional 2014 plume interpretation developed in ECF-200UP1-14-0019, *Initial Groundwater Plume Development (Uranium, Technetium-99, Nitrate, and Iodine-129) to Support Fate and Transport Modeling for Remedial Design in the 200 UP-1 Groundwater Operable Unit*, that was extended for all layers representing the Ringold Formation member of Wooded Island – unit E (Rwie) formation. Figure 2-1 includes the 2014 and 2017 plume contour line representing values above the cleanup level (1 pCi/L) as documented in the annual groundwater monitoring report, and the yearly averaged concentrations used for the 2017 plume construction. In general, the plume shows a similar geometry with concentration decreases along the northeastern leading edge consistent with the location of the three injection wells used for containment. For the 2017 plume development, the highest concentration value in the 200-UP-1 OU is at well 299-W21-3 near the Environmental Restoration Disposal Facility (ERDF) southwest boundary with an average value in year 2017 of 20.52 pCi/L. DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017* provides an additional overview of the maximum concentration values observed at the waste sites that generated that I-129 plume.

The hydraulic containment is based on injection wells placed at the northeast edge of the I-129 plume. Treated water from the 200 West P&T Facility, extracted from areas outside the I-129 plume, is pumped to the injection wells. Previous analysis estimated that three injection wells with a flow rate of 50 gal/min per well (150 gal/min total) will be needed to hydraulically control the plume. ECF-200UP1-14-0053 also identified an upper limit of 300 gal/min to arrest the leading edge of the plume (450 gal/min was observed to generate local reversal of flow). Since the containment injection operations started, injection reached a total average of 134 gal/min in 2015, 204 gal/min in 2016, and 223 gal/min in 2017. Projections used in this analysis, based on pumping projections for the 200 West Groundwater Treatment Facility in ECF-200ZP1-19-0103, *Extraction Well Location and Rate Optimization in Support of the 200-ZP-1 Optimization Test Plan*), estimate a constant pumping of 225 gal/min for future years until the cessation of hydraulic containment. This analysis seeks to evaluate the impact of ceasing injection pumping at two different time horizons: end of 2037 (Scenario 1) and end of 2020 (Scenario 2) and the subsequent fate and transport of the plume.

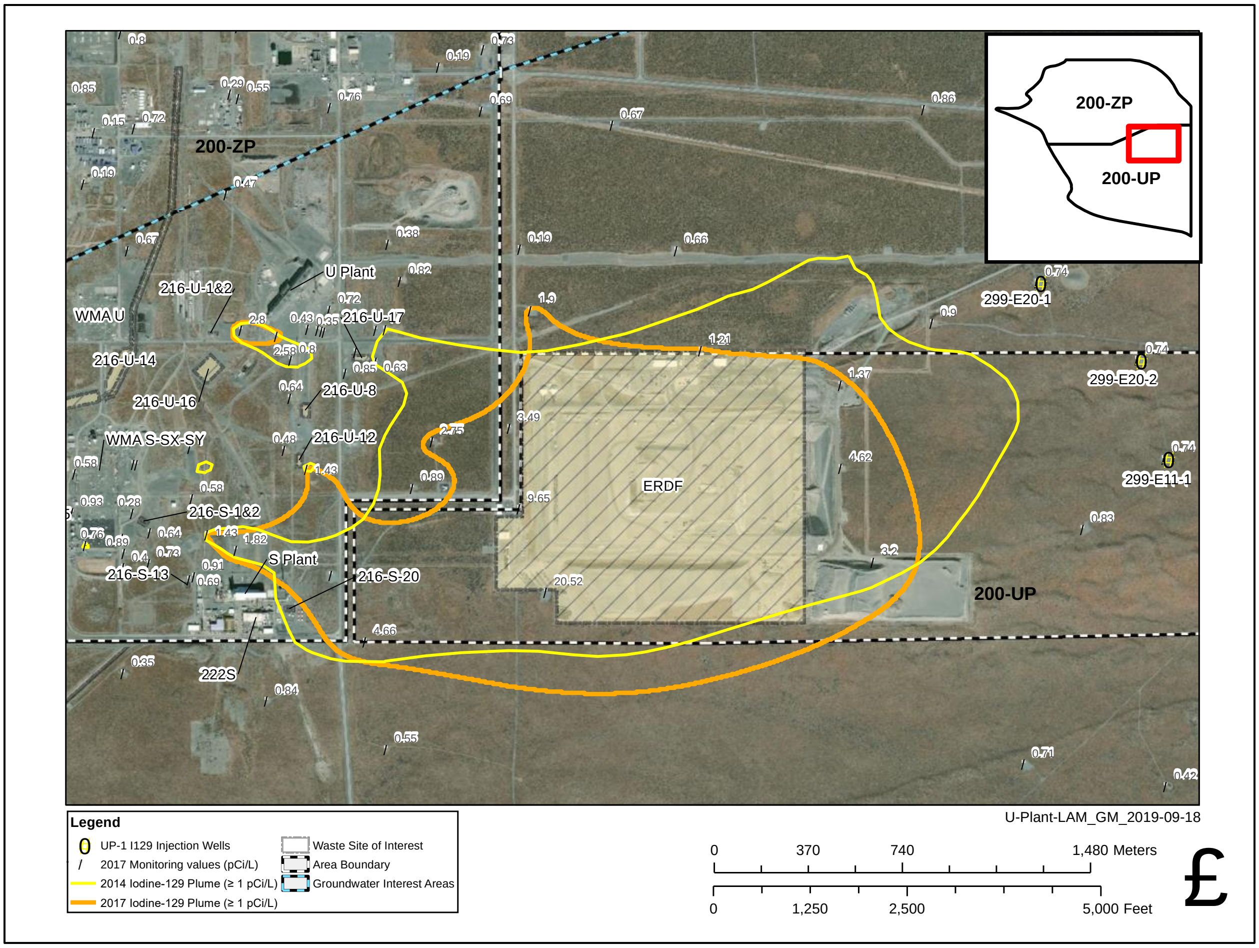

Figure 2-1. Comparison of 2014 and 2017 Iodine Plumes in the 200-UP-1 OU, Relevant Waste Sites, and Location of 2017 Monitoring Values

3 Methodology

This chapter gives a summary of the plateau-to-river (P2R) model used for the fate and transport modeling of I-129 plume, and the postprocessing of transport model output for the analysis. The details on the P2R model version 8.3 are described in ECF-HANFORD-21-0004, *Predictive Flow Simulation with the P2R Model for the Cumulative Impact Evaluation No Further Action Scenario* and ECF-HANFORD-21-0005, *Predictive Contaminant Transport Simulation with the P2R Model for the Cumulative Impact Evaluation No Further Action Scenario*.

3.1 Groundwater Flow Modeling

The past hydraulic containment analyses of I-129 were performed using the Central Plateau groundwater model (CPGWM). However, the CPGWM has been superseded by the P2R model version 8.3. The P2R model was used to calculate the necessary flow velocity fields and sink/source sinks before using Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems modeling (MT3DMS) software for transport analysis. Groundwater flow was simulated using MODular three-dimensional groundwater FLOW (MODFLOW[1]) model software (Harbaugh et al., 2000, *MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*).

3.1.1 Model Domain and Discretization

The P2R model domain has the following lateral extent and boundaries: extent north to south is 26.6 km (16.5 mi) and extent east to west is 37.6 km (23.3 mi). The lower left corner of the model domain is located at easting 557,800 m and at northing 116,200 m in the Washington State Coordinate System (NAD_1983_StatePlane_Washington_South_FIPS_4602) (NAD83, *North American Datum of 1983*). The vertical extent of the model comprises the subsurface sediments from ground surface to the uppermost unit of the Columbia River Basalt Group. The basalt that is assumed to constitute an impermeable lower boundary defines the base of the domain.

The model domain is discretized into a finite difference grid. The grid in the lateral directions is broken into variably sized cells of 100 by 100 m (328.1 by 328.1 ft), 100 by 200 (328.1 by 656.2 ft), and 200 by 200 m (656.2 by 656.2 ft). A total of 274 columns and 201 rows constitutes a total of 55,074 laterally distinct cell locations within the model domain. The model is vertically divided into seven model layers between the ground surface elevation and the top of the uppermost basalt surface. The discretization of the vertical layers varies to represent the thickness of geologic formations found within the model domain. A maximum of 34,421 of those 55,074 laterally distinct cells is active in the model within each model layer. Figure 3-1 shows the lateral extent of the P2R model version 8.3 domain along with the groundwater OUs, lateral discretization, and boundary conditions.

[1] MODFLOW is a product of the U.S. Geological Survey, Reston, Virginia.

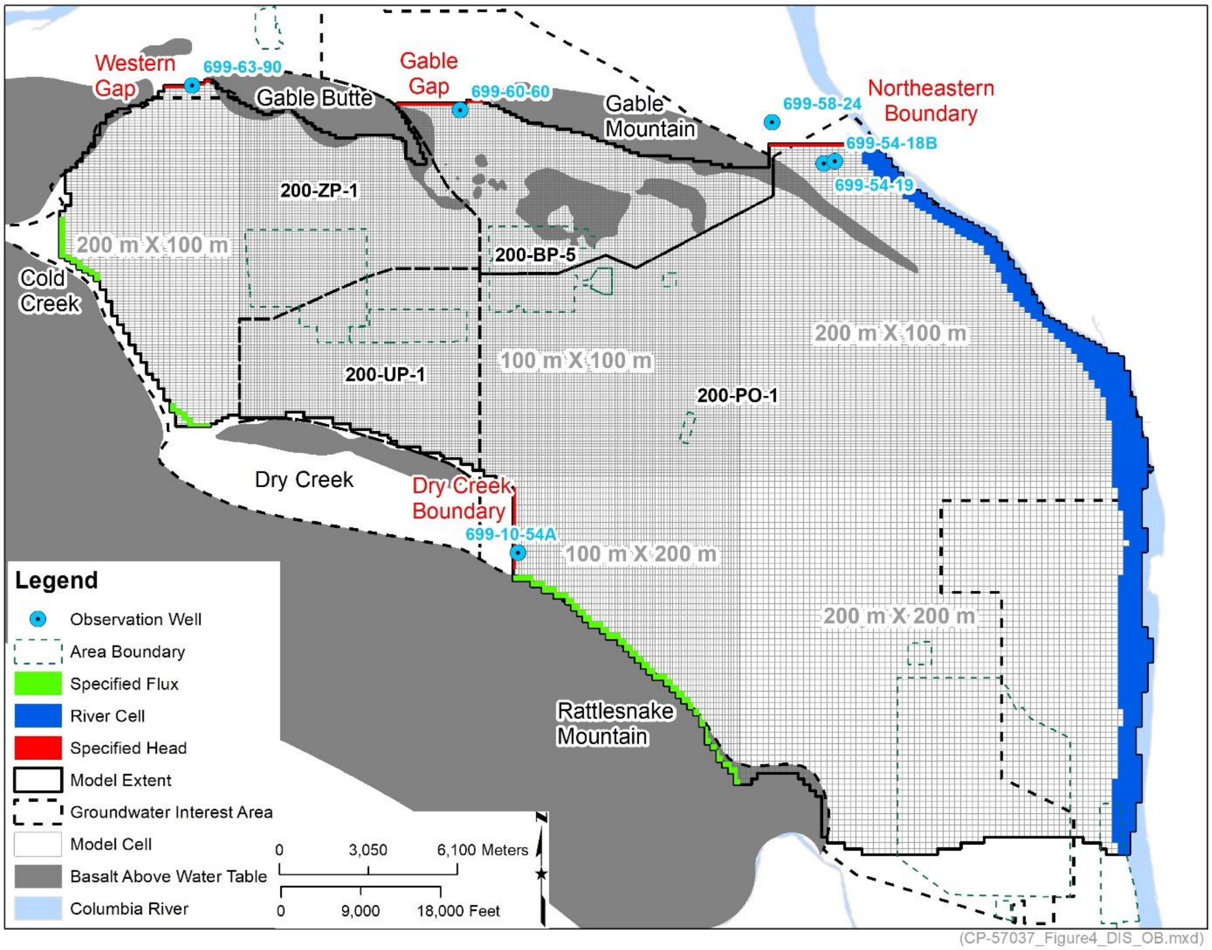

Figure 3-1. P2R Model Version 8.3 Extent and Boundary Conditions

3.1 Groundwater Transport Modeling

Contaminant transport simulations were performed using MT3DMS, which simulates advection, dispersion, source/sinks, and chemical reactions (Zheng and Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*). MT3DMS is designed for use with finite difference flow models, such as MODFLOW 2000 (Harbaugh et al., 2000). The flow model provides the velocity field needed for transport simulations. Transport simulations were conducted to evaluate the fate of the 200-UP-1 OU plume and the 200-UP-1 and 200 East I-129 combined plumes. The approach to using MT3DMS was as follows:

- Generate the input files for the predictive flow model. The details on the predictive flow model input files are summarized in Section 4.1 of this ECF.
- Execute the predictive flow model.
- Generate the input files for MT3DMS. Input data are described in Section 4.2 of this ECF.
- Link the simulated flow field to the MT3DMS simulation.

- Execute the MT3DMS model simulations making use of the Transport Observation Package to gather output concentrations at specific times and locations needed for estimation of 95%UCL mean concentrations (explained in Section 3.2). Addition of the wells required for 95%UCL network is explained in Section 4.2.5.
- Evaluate the transport models for each scenario through different methods as follows:
  - 95%UCL mean concentration in the monitoring wells network
  - Maps of maximum concentration over all the layers in the P2R model
  - Time series plots of simulated maximum concentration of the entire aquifer
  - Time series plots of the simulated plume area for the selected plume contours

The transport parameters used for the fate and transport analysis of I-129 are the same as documented in ECF-HANFORD-21-0005 and are described in Section 4.2.2 of this ECF.

3.2 95%UCL Computation of Mean Plume Concentration

Simulated remediation performance was evaluated by calculating the 95%UCL on mean plume concentrations. This is the same method recommended for calculating groundwater plume exposure point concentrations in superfund risk assessment guidance (OSWER Directive 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*). The advantage of the 95%UCL is that it provides a comprehensive evaluation of plume concentrations in a single metric and is calculated using sample results or simulated concentrations at monitoring wells.

The one-sided 95%UCL was calculated using Student's *t* test assuming a normal distribution (OSWER Directive 9285.6-10):

$$95\%\text{UCL} = \bar{X} + t_{\alpha,n-1}\frac{s}{\sqrt{n}} \qquad \textbf{(Eq. 3-1)}$$

where:

$\bar{X}$	=	arithmetic mean of the sample results
$t_{\alpha,n\text{-}1}$	=	the 1-α^{th} quantile of Student's *t* distribution with *n*-1 degrees of freedom; for the 95th percentile, α = 0.95 (one-tailed)
s	=	standard deviation of the sample results
n	=	number of samples.

The well network for I-129 calculations is explained in Section 4.2.5. This network was based on the current monitoring network and future distribution of the I-129 plume. Calculations of 95%UCLs for transport simulation results were performed as follows:

1. Wells in the monitoring network with concentrations above the cleanup level at the start of the simulations were selected for use in 95%UCL calculations.
2. 95%UCLs were calculated annually beginning in 2018 (the first year of the transport simulations). The calculations used simulated concentrations at the end of each year. Three years of data were compiled for the calculations. For example, the data used for calculations of a 2021 95%UCL consisted of concentrations at the end of 2019, 2020, and 2021. This ensured that enough data were available for representative calculation results. When 3 years of data were not available, one or two

years of data were used. For example, in 2018, the 2018 data were used, and in 2019, the 2018 and 2019 data were used.

3. As the plume moved into areas not covered by the active wells, additional wells were added to the calculation dataset. This was done when concentrations at a nearby well, or a synthetic well, increased to above the cleanup level. When a new well was added, the convention of using 3 years of data was applied (i.e., if a well increased to above the cleanup level in 2030, concentrations for 2028, 2029, and 2030 were used in the calculation beginning in 2030).

4. When concentrations in a well declined to below one-tenth of the cleanup level that well was dropped from the calculation (this cutoff was specified in DOE/RL-2015-14, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*). However, if concentrations in that well later increased to above one-tenth the cleanup level, it was added back into the calculation. In other words, once a well is part of the 95%UCL network, it is always used in the calculation if the concentration is above one-tenth the cleanup level.

5. Calculations were performed until the end of the simulation data set, or until there were fewer than two data points above one-tenth the cleanup level available for the calculation. The use of only two data points occurred in some of the simulations performed when plume concentrations were very low, and the mean plume concentration was well below the cleanup level. Thus, the effect of using only a few data points in the calculation was considered insignificant.

4 Assumptions and Inputs

This chapter summarizes the inputs that are specific to the calculations presented in this ECF. Features and inputs to the P2R model (e.g., model layer elevations, hydraulic properties, specific storage, and specific yield) that did not change from the P2R model are not presented, and the reader is directed to CP-57037, *Model Package Report: Plateau to River Groundwater Model Version 8.3*. Features and inputs that did change in ECF-HANFORD-21-0004 and ECF-HANFORD-21-0005 are presented below for the convenience of the reader. The principal inputs to the flow calculations include the following:

- Temporal discretization (i.e., stress period [SP])
- Boundary conditions
- Initial head
- Extraction and injection well flow rates by SP
- Pumping scenarios

The principal inputs to the transport calculations are:

- Initial concentrations (ICs)
- Transport parameters
- Continuing sources
- Well monitoring network for 95%UCL

4.1 Groundwater Flow Modeling

The P2R model version 8.3 used for the flow model in this calculation is documented in ECF-HANFORD-21-0004 as developed for the cumulative impact evaluation (CIE). The flow model features that were used in ECF-HANFORD-21-0004 are described in the following sections.

4.1.1 Temporal Discretization

The simulation period for the predictive flow model starts in 2018 and runs for 1,052 years, ending in 3070. The temporal discretization of the predictive flow model is listed in Table 4-1. A total of 101 SPs were used with varying SP length. The length of any SP through 2570 matched the time periods taken by the recharge evolution tool documented in ECF-HANFORD-15-0019, *Hanford Site-wide Natural Recharge Boundary Conditions for Groundwater Models*. By staying consistent with the recharge evolution tool temporal discretization, major changes to land use were represented in the boundary conditions of the simulation.

Table 4-1. Temporal Discretization of Predictive Flow Model

Stress Periods	Duration (yr)	Description
1 to 82	82	82 transient annual stress periods that span from 2018 through 2099
83	35	1 transient stress period that spans from 2100 through 2134
84	16	1 transient stress period that spans from 2135 through 2150
85	343	1 transient stress period that spans from 2151 through 2493
86	23	1 transient stress period that spans from 2494 through 2516

Table 4-1. Temporal Discretization of Predictive Flow Model

Stress Periods	Duration (yr)	Description
87	3	1 transient stress period that spans from 2517 through 2519
88	1	1 transient annual stress period that spans the year 2520
89	4	1 transient stress period that spans from 2521 through 2524
90 to 91	2	2 transient annual stress periods that span from 2515 through 2526
92	2	1 transient stress period that spans from 2527 through 2528
93	1	1 transient annual stress period that spans the year 2529
94	3	1 transient stress period that spans from 2530 through 2532
95	2	1 transient stress period that spans from 2533 through 2534
96	8	1 transient stress period that spans from 2535 through 2542
97	7	1 transient stress period that spans from 2543 through 2549
98 to 99	2	2 transient annual stress periods that span from 2550 through 2551
100	18	1 transient stress period that spans from 2552 through 2569
101	500	1 transient stress period that spans from 2570 through 3070

4.1.2 Boundary Conditions

Boundary conditions for the P2R model were adjusted to match the temporal discretization needed to simulate 1,000 years into the future from site closure in calendar year 2070. Updated boundary conditions include the Columbia River boundary, specified heads, and the recharge. Each of these is discussed in the following sections.

4.1.2.1 Columbia River Boundary

The Columbia River acts as the eastern boundary condition for the P2R model. The details on the river boundary features such as river cell location, river stage elevation, river bottom elevation, and river sediment conductance are documented in CP-57037. The process for building the Columbia River boundary condition was kept same as the one documented in CP-57037. The flow rates at the river gage for first two SPs (2018 and 2019) were available during the predictive simulation period. The yearly averaged flow data were used to calculate river stage for 2018 and 2019. The river stage for the remainder of the simulation period was kept constant which was calculated by averaging the flow rates from last 20 years of river gage data (2000 to 2019). A 20-year average was chosen because of its similarity to the 10- and 71-year averages and was consistent with the average timeframe used for the specified heads at Gable Gap and Dry Creek.

4.1.2.2 Specified Heads

The basalt top elevation defines the bottom and most of the lateral boundaries of the model domain (depicted as dark gray-colored regions in Figure 3-1). Four locations where the water table is above the top of the basalt are defined by specified head boundaries (shown as red shading in Figure 3-1). For the historical period as documented in CP-57037, the specified head values at each of these specified head boundary locations were taken as the annual average observed head at observations wells near the boundary location. However, such observation data are not possible for the predictive model starting from 2020. For the western Gap and northeastern boundary, constant values of 122.5 and 110.98 m (representative of the average of the last 20 years of data) were used, respectively. For the Gable Gap and southern boundary near Dry Creek, the specified heads were developed using an exponential equation defined by the observed trend at wells 699-60-60 and 699-10-54A, respectively. The parameters for the exponential equations were estimated using the least squares regression (LSQR) fitting of the observed values. The following exponential equation was used for calculating the specified head boundary condition:

$$P_i = B + e^{(-X * (Y_i - Y_0))} * (S - B) \quad \textbf{(Eq. 4-1)}$$

where:

P_i = the predicted head for the year i

B = the base head representing pre-Hanford (01/01/1945) water table

X = a fitting parameter

Y_i = the year of the specified head to be predicted

Y_0 = the starting year of the LSQR fitting dataset

S = the start head representative of the starting year, Y_0.

LSQR fitting parameters are listed in Table 4-2.

The observed and predicted heads calculated using the corresponding fitted exponential equation are shown in Figure 4-1 at the northern specified head boundary at Gable Gap near well 699-60-60, and in Figure 4-2, at the northern specified head boundary at Dry Creek near well 699-10-54A.

Table 4-2. LSQR Fitting Parameters Used for Predicting Specified Head at Gable Gap and Southern Boundary near Dry Creek

Parameters	Gable Gap	Dry Creek
B (m)	120.6	122.1
X (dimensionless)	0.0256	0.0076
(yr)	2,003.5	2,003.5
S (m)	122.2	126.98

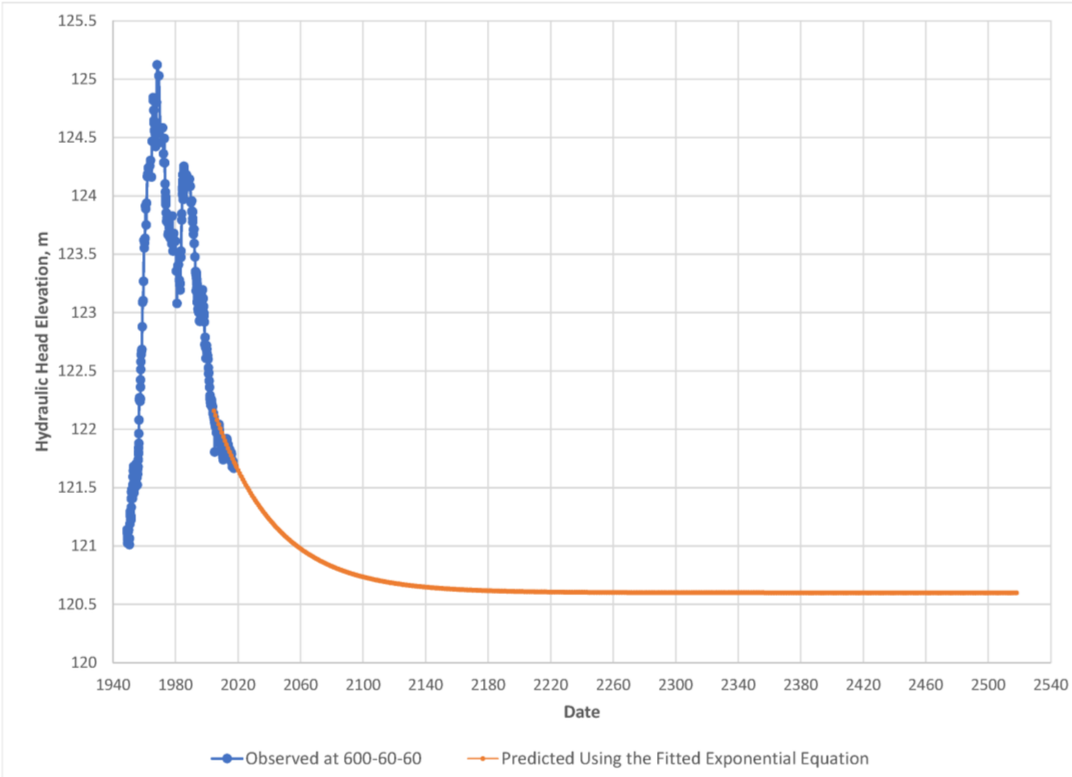

Figure 4-1. Observed Head Values and Estimated Exponential Regression Function at the Northern Specified Head Boundary at Gable Gap Near Well 699-60-60 for the Predictive Model

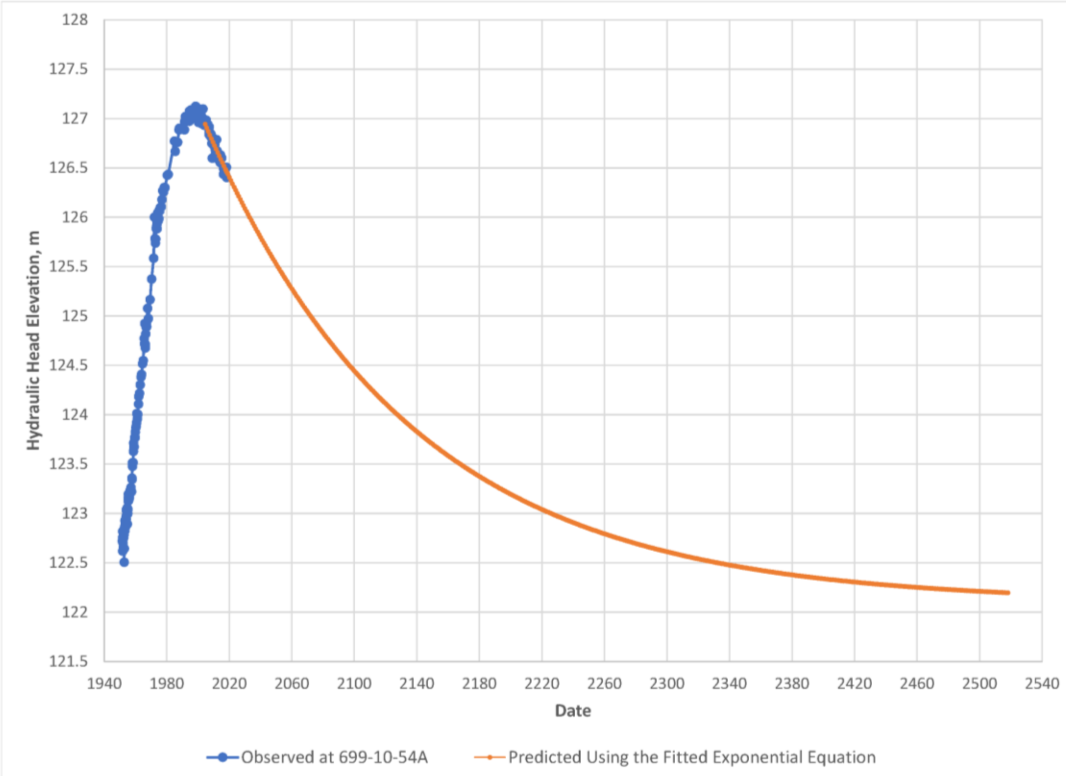

Figure 4-2. Observed Head Values and Estimated Exponential Regression Function at the Western Specified Head Boundary at Dry Creek Near Well 699-10-54A for the Predictive Model

4.1.2.3 Recharge

Recharge at the water table in the P2R model includes the contributions to total recharge from the following components:

- **Natural recharge:** Deep percolation of precipitation that is not evaporated/transpired and is not retained in storage in the vadose zone.
- **Mountain-front recharge:** Contribution to the groundwater flux from upgradient sources to the aquifer including Rattlesnake Mountain and the Dry Creek and Cold Creek watersheds.
- **Anthropogenic recharge:** Historical wastewater discharges at the Hanford Site.

For each SP of the model, these individual components are summed to create the total recharge to the aquifer. The summed values are input into a MODFLOW recharge package for inclusion in the model simulation. The recharge components for the predictive model are consistent with the methodologies documented as part of the historic calibration documented in CP-57037. Changes were made to values to match the difference in the temporal domain of the model. These aspects are discussed in ECF-HANFORD-21-0004.

4.1.3 Initial Head

The initial hydraulic head for the predictive model was extracted from the simulated head output of the historic calibration of the P2R model version 8.3 (CP-57037) at the end of 2017. This coincided with SP 141 timestep 1 of the P2R model historic calibration.

4.1.4 Extraction and Injection Wells

The predictive flow model includes all the extraction/injection wells used in ECF-HANFORD-20-0049, *Description of Groundwater Calculations to Support Performance Assessment for the Calendar Year 2019 (CY 2019) 200 Areas Pump-and-Treat Report*. The P&T model had pumping starting in either 2012 or 2015 and ending at the end of September 2037, with monthly SPs from the model start through the end of September 2022. It then uses annual SPs from October 2022 through September 2037. The P2R model as applied to the CIE predictive model utilizes annual SPs during that time period. To assign the appropriate pumping rates to the P2R model version 8.3 predictive model, the following methods were used:

- Monthly SPs in the P&T model (SP 37-84 for the 2015-start model) representing January 2018 through December 2021, were used to create a single average value for calendar years 2018 through 2021 (P2Rv8.3 SP 1-4).
- For model year 2022, a weighted average of P&T model monthly values for January through September (SP 85-93) and the annual value starting in October 2022 (SP 94) was computed for calendar year 2022 (P2Rv8.3 SP 5).
- For model years 2023 through 2037, a weighted average of the P&T model annual values for October 2022 through September 2037 (P&T SP 94-109) was computed for CYs 2023 through 2037 values (P2Rv8.3 SP 6–20).
- For model year 2038 and all subsequent P2Rv8.3 SPs, all pumping was shut off (P2Rv8.3 SP 21-101).

The resulting injection and extraction rates are summarized in Table 4-3.

Table 4-3. Extraction and Injection Rates for Each Stress Period in the CIE

Date	2018	2019	2020	2021	2022-2036	2037	2038-2070
Stress Period	1	2	3	4	5-19	20	21-101
Well Name							
299-E11-1	76.4	72.9	50.0	50.0	50.0	37.5	0.0
299-E20-1	71.7	71.4	50.0	50.0	50.0	37.5	0.0
299-E20-2	75.3	66.4	50.0	50.0	50.0	37.5	0.0
299-E33-268	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-E33-360	-162.8	-125.7	-110.0	-110.0	-110.0	-82.5	0.0
299-E33-361	0.0	-35.2	-50.0	-50.0	-50.0	-37.5	0.0
299-W10-35	108.5	118.9	130.0	128.3	130.0	97.5	0.0
299-W10-36	60.7	17.8	130.0	128.3	130.0	97.5	0.0
299-W11-103	0.0	0.0	0.0	-129.2	-130.0	-97.5	0.0
299-W11-104	0.0	0.0	0.0	-132.5	-130.0	-97.5	0.0
299-W11-45	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4-3. Extraction and Injection Rates for Each Stress Period in the CIE

Date	2018	2019	2020	2021	2022-2036	2037	2038-2070
Stress Period	1	2	3	4	5-19	20	21-101
Well Name							
299-W11-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W11-49	-133.1	-114.7	-130.0	-125.8	-120.0	-90.0	0.0
299-W11-50	-58.0	-55.9	-60.0	-83.3	-100.0	-75.0	0.0
299-W11-90	-88.4	-87.5	-100.0	-114.2	-100.0	-75.0	0.0
299-W11-92	-78.1	-96.1	-110.0	-89.2	-50.0	-37.5	0.0
299-W11-96	-106.6	-78.2	-100.0	-113.3	-120.0	-90.0	0.0
299-W11-97	-92.8	-103.6	-125.0	-118.8	-60.0	-45.0	0.0
299-W12-2	-107.5	-95.8	-105.0	-104.2	-100.0	-75.0	0.0
299-W12-3	-98.2	-90.1	-100.0	-100.0	-80.0	-60.0	0.0
299-W12-4	-129.3	-121.7	-130.0	-125.0	-110.0	-82.5	0.0
299-W12-5	0.0	0.0	0.0	-129.6	-130.0	-97.5	0.0
299-W14-20	-74.9	-99.6	-105.0	-102.9	-100.0	-75.0	0.0
299-W14-21	-93.2	-89.7	-90.0	-90.0	-90.0	-67.5	0.0
299-W14-22	-103.2	-102.5	-115.0	-114.6	-100.0	-75.0	0.0
299-W14-27	0.0	0.0	0.0	-95.8	-150.0	-112.5	0.0
299-W14-28	0.0	0.0	0.0	-119.6	-130.0	-97.5	0.0
299-W14-30	0.0	0.0	0.0	-69.2	-130.0	-97.5	0.0
299-W14-31	0.0	0.0	0.0	-56.7	-130.0	-97.5	0.0
299-W14-32	0.0	0.0	0.0	-21.7	-130.0	-97.5	0.0
299-W14-33	0.0	0.0	0.0	-10.8	-130.0	-97.5	0.0
299-W14-73	-135.3	-82.7	-130.0	-125.0	-110.0	-82.5	0.0
299-W14-74	-100.9	-95.7	-105.0	-104.2	-100.0	-75.0	0.0
299-W15-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-225	-39.0	-79.9	-100.0	-84.2	-50.0	-37.5	0.0
299-W15-226	168.6	142.8	130.0	128.3	130.0	97.5	0.0
299-W15-227	140.0	142.1	140.0	130.0	130.0	97.5	0.0
299-W15-228	109.8	111.0	130.0	130.0	130.0	97.5	0.0
299-W15-229	75.0	82.7	120.0	136.7	150.0	112.5	0.0

Table 4-3. Extraction and Injection Rates for Each Stress Period in the CIE

Date	2018	2019	2020	2021	2022-2036	2037	2038-2070
Stress Period	1	2	3	4	5-19	20	21-101
Well Name							
299-W15-29	60.4	91.1	120.0	120.0	120.0	90.0	0.0
299-W15-32	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-34	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-35	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-36	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-37	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-40	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-43	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-44	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-45	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-47	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W15-765	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W17-2	0.0	-58.2	-100.0	-102.1	-50.0	-37.5	0.0
299-W17-3	-73.2	-99.4	-110.0	-93.3	-50.0	-37.5	0.0
299-W18-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W18-36	16.1	64.6	100.0	100.0	100.0	75.0	0.0
299-W18-37	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W18-38	66.3	44.9	95.0	102.5	110.0	82.5	0.0
299-W18-39	2.0	25.0	15.0	17.5	25.0	18.8	0.0
299-W18-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W18-41	133.4	115.5	130.0	129.2	130.0	97.5	0.0
299-W18-42	134.7	85.6	130.0	138.3	150.0	112.5	0.0
299-W18-43	139.6	69.5	110.0	130.4	135.0	101.3	0.0
299-W18-44	0.0	0.0	0.0	119.2	130.0	97.5	0.0
299-W19-111	0.0	-7.6	-10.0	-10.0	-10.0	-7.5	0.0

Table 4-3. Extraction and Injection Rates for Each Stress Period in the CIE

Date	2018	2019	2020	2021	2022-2036	2037	2038-2070
Stress Period	1	2	3	4	5-19	20	21-101
Well Name							
299-W19-113	-43.5	-46.6	-50.0	-50.0	-50.0	-37.5	0.0
299-W19-114	-54.3	-71.5	-80.0	-80.0	-80.0	-60.0	0.0
299-W19-125	-49.4	-47.6	-40.0	-40.0	-40.0	-30.0	0.0
299-W19-23	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W19-24	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W19-25	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W19-36E	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W19-36I	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W19-39	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W19-43	0.0	0.0	0.0	0.0	0.0	0.0	0.0
299-W22-90	-24.7	-20.5	-25.0	-25.0	-25.0	-18.8	0.0
299-W22-91	-29.3	-29.5	-30.0	-30.0	-30.0	-22.5	0.0
299-W22-92	-24.8	-24.4	-25.0	-25.0	-25.0	-18.8	0.0
299-W5-1	-78.0	-86.4	-100.0	-87.5	-50.0	-37.5	0.0
299-W6-13	57.9	54.5	130.0	129.2	130.0	97.5	0.0
299-W6-14	174.0	101.1	140.0	130.0	130.0	97.5	0.0
299-W6-15	-95.9	-75.3	-90.0	-101.7	-100.0	-75.0	0.0
299-W6-16	0.0	0.0	0.0	119.2	130.0	97.5	0.0
299-W7-14	104.7	83.5	120.0	129.6	135.0	101.3	0.0
699-38-64	90.4	101.7	50.0	49.2	50.0	37.5	0.0
699-40-67	39.3	78.2	50.0	53.3	60.0	45.0	0.0
699-40-70A	0.0	0.0	0.0	0.0	-130.0	-97.5	0.0
699-42-67	57.3	101.0	50.0	125.0	140.0	105.0	0.0
699-43-67	21.7	47.6	50.0	62.5	70.0	52.5	0.0
699-43-67B	14.5	20.5	20.0	25.4	30.0	22.5	0.0
699-44-67	16.6	36.6	50.0	52.9	60.0	45.0	0.0
699-45-67	28.5	35.4	50.0	47.9	60.0	45.0	0.0
699-45-67B	3.9	33.4	20.0	23.3	25.0	18.8	0.0
699-46-68	41.5	59.2	90.0	90.8	100.0	75.0	0.0

Table 4-3. Extraction and Injection Rates for Each Stress Period in the CIE

Date	2018	2019	2020	2021	2022-2036	2037	2038-2070
Stress Period	1	2	3	4	5-19	20	21-101
Well Name							
699-47-78	0.0	0.0	0.0	126.7	150.0	112.5	0.0
699-47-78B	0.0	0.0	0.0	125.8	150.0	112.5	0.0
699-47-78C	0.0	0.0	0.0	125.8	150.0	112.5	0.0
699-48-70	0.0	-6.0	-75.0	-87.9	-100.0	-75.0	0.0
699-49-69	20.6	50.2	50.0	46.7	60.0	45.0	0.0

Note: Extraction and injection rates are shown in gallons per minute.

4.1.5 Pumping Scenarios

Two P&T scenarios were considered for evaluating the effects of hydraulic containment injection wells on the I-129 plume within the 200-UP-1 OU. These scenarios are as follows:

- Scenario 1: All the extraction/injection wells in 200 West (200-ZP-1 and 200-UP-1) active in 2019 are continued through the end of 2037 (as shown in Table 4-3).
- Scenario 2: All the extraction/injection wells that are active 200 West in 2019 are continued through the end of 2037 except the I-129 injection wells (299-E20-1, 299-E20-2, and 299-E-11-1) are turned off at the end of 2020.

Table 4-4 provides the injection rates of the I-129 hydraulic containment wells used in the predictive models for both scenarios. Figure 4-3 shows the location of wells used in this ECF.

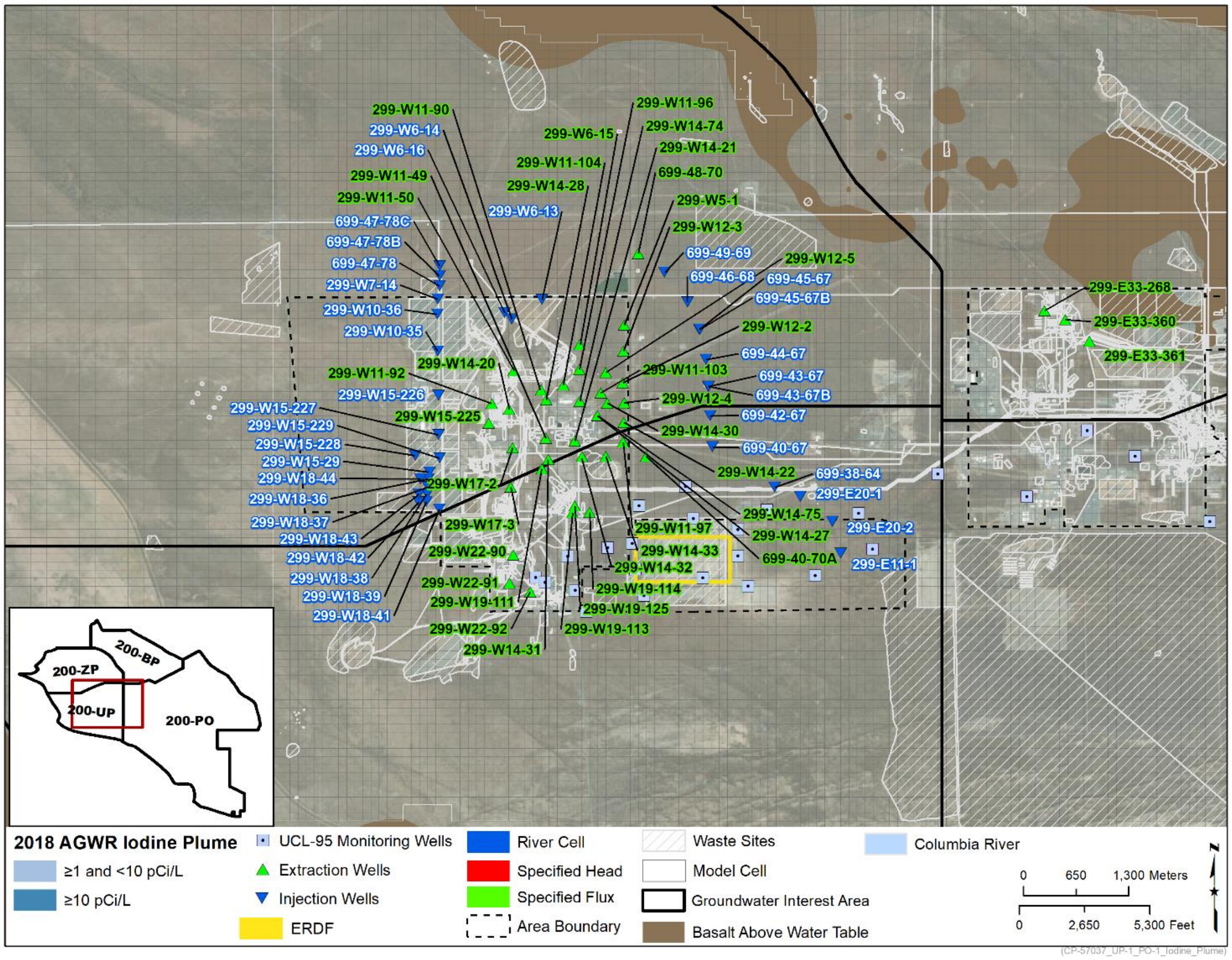

Figure 4-3. Pump-and-Treat Well Locations

Table 4-4. Projected Injection Well Rates Used in this Analysis

Injection Well Name	Injection Rate (gal/min)				
	2018	2019	2020-2036	2037	2038-3070
Scenario 1					
299-E11-1	76.4	72.9	50.0	37.5	0.0
299-E20-1	71.7	71.4	50.0	37.5	0.0
299-E20-2	75.3	66.4	50.0	37.5	0.0
Total	223	211	150	113	0.0
Injection Well Name	**2018**	**2019**	**2020**	**2021-3070**	
Scenario 2					
299-E20-1	76.4	72.9	50.0	0.0	
299-E20-2	71.7	71.4	50.0	0.0	
299-E11-1	75.3	66.4	50.0	0.0	
Total	223	211	150	0.0	

4.2 Groundwater Transport Modeling

This section describes the development of the I-129 plume for the numerical model scenarios and the transport properties used.

4.2.1 Initial concentration

The initial concentration distribution was estimated for I-129. The process for developing the estimate is documented in ECF-HANFORD-20-0062, *Mapping the Concentration Distribution of Contaminant Plumes to the Computational Grid of the Plateau to River Model Version 8.3*. In summary, observed concentration data at wells and two- and three-dimensional interpolations of plume concentration distribution were used to map plume concentration to the model grid. For this ECF, the maximum concentration (worst case) plume was used. In addition, the initial concentration for this calculation was filtered to include only the plume within the 200-UP-1 OU.

Figure 4-4 through Figure 4-5 show the initial concentration used in each model layer for this ECF. No concentration is assigned in most of the cells in Layer 1 as this layer is mostly above the water table.

4.2.2 Transport Parameters

The transport parameters used for this ECF are the same as those used in ECF-HANFORD-21-0005 and are selected from characterization data compiled in reports specific to the Hanford Site or based on literature values, where necessary, that are documented in the tables presented in the following sections. The parameter values reflect information that are typically used to support fate and transport modeling in support of remedial decisions at the Hanford Site. These parameters include soil properties, geochemical properties, and dispersion.

4.2.2.1 Soil Properties

Soil properties for the fate and transport simulation are shown in Table 4-5. The effective porosity and bulk density values are provided with their respective geologic units. The basis for each selected parameter value is also included in the table.

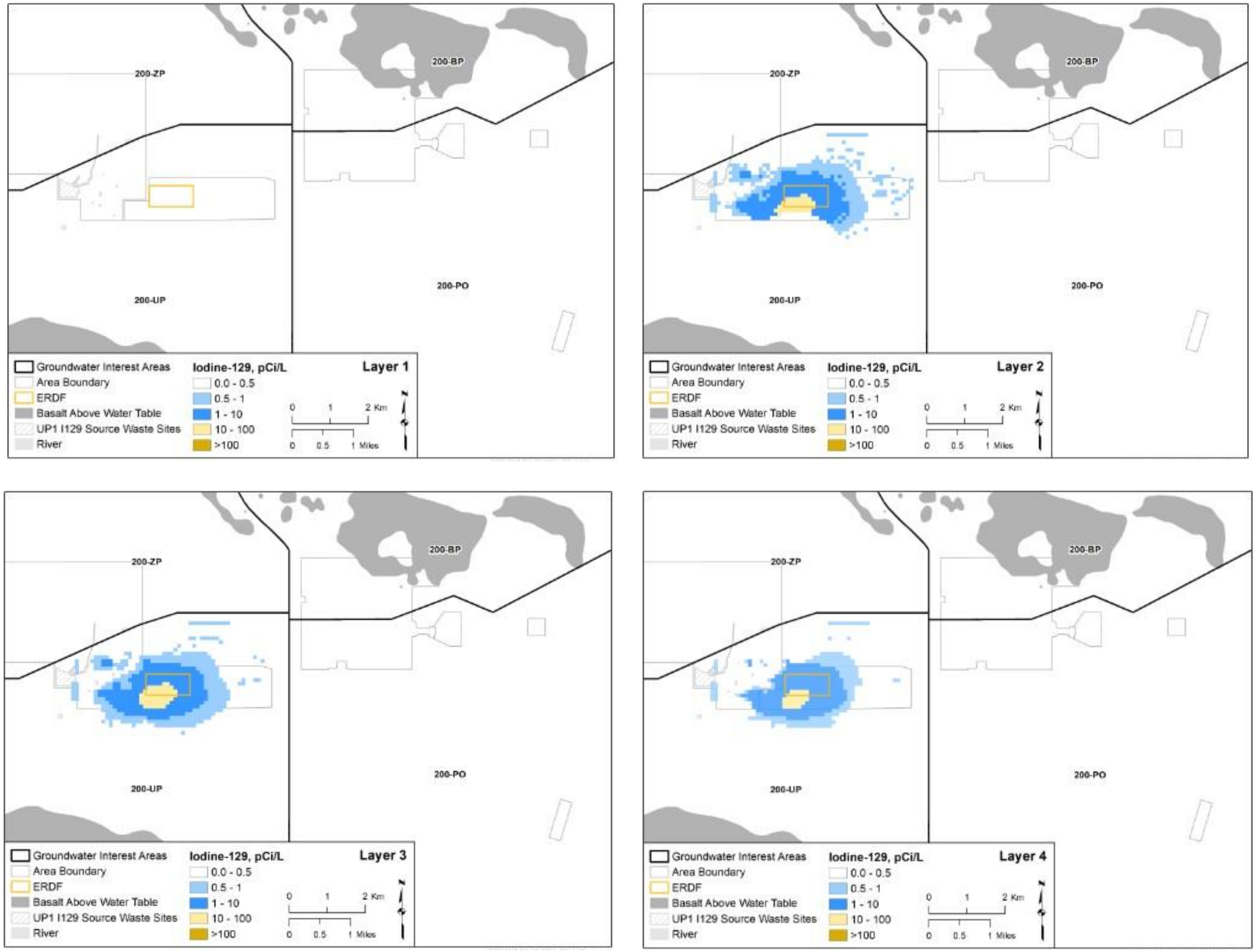

Figure 4-4. Initial Concentration of the I-129 Plume in the 200-UP-1 OU (Layers 1 through 4)

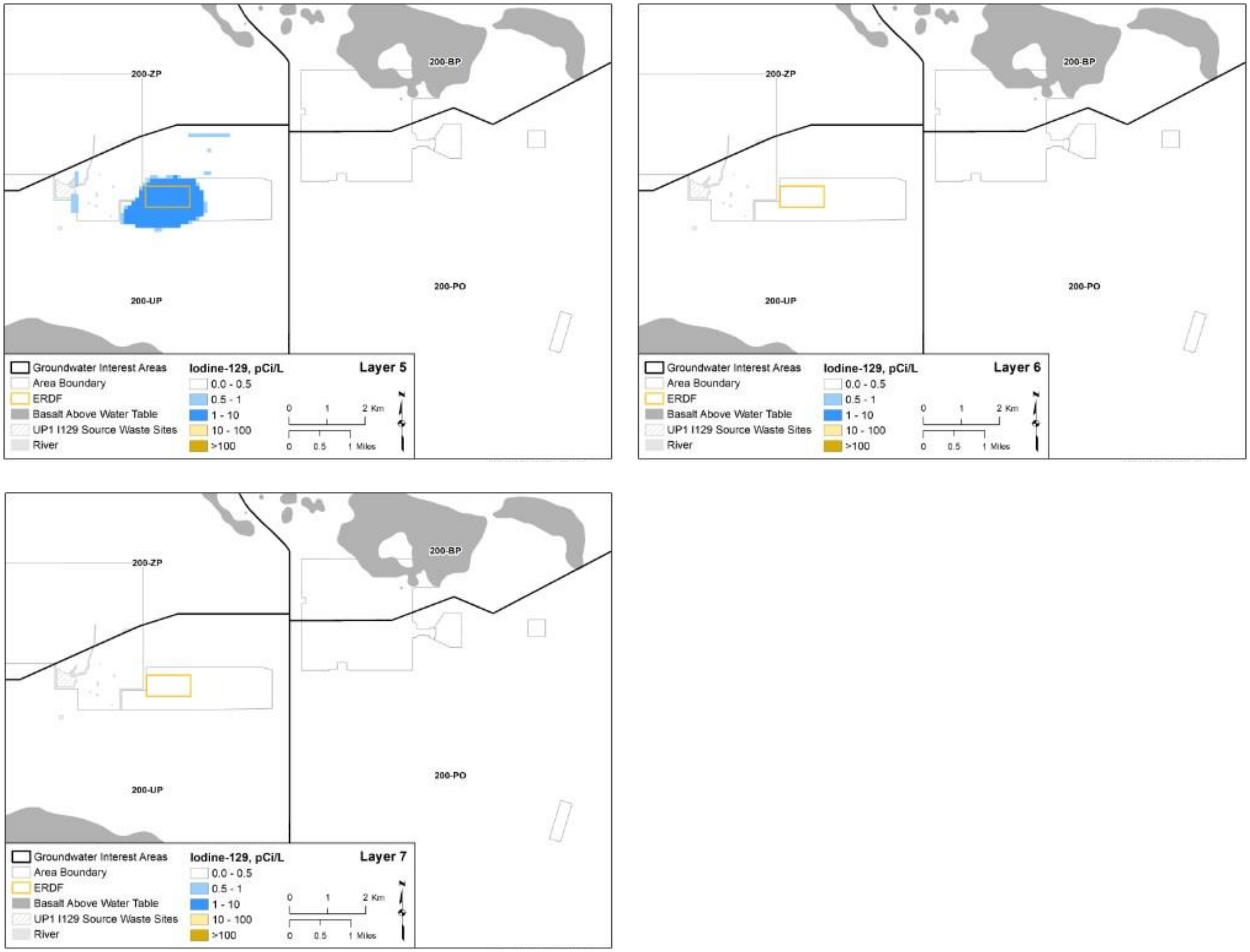

Figure 4-5. Initial Concentration of the I-129 Plume in the 200-UP-1 OU (Layers 5 through 7)

Table 4-5. Composite Analysis Saturated Zone Facet Transport Model Soil Properties

Property	Geologic Unit	Value	Basis
Effective Porosity	Hanford formation, Cold Creek unit	0.2	Approximate central value (arithmetic average) of the mean value for all Hanford sediments representative of the saturated zone – either estimated, interpreted from aquifer tests or tracer tests, or calculated from lab tests on samples taken from within 5 m above the water table to the bottom of a specified borehole (Table D-17 in DOE/RL-2007-28). Textural description is assumed to approximate the gravelly sand or sandy gravel Cold Creek unit described in PNNL-18564 and the basis for its assigned bulk density of 1.93 g/cm^3.
	Ringold Formation member of Taylor Flat, Ringold Formation Member of Wooded Island – unit E, Ringold Formation Member of Wooded Island – unit A	0.15	Approximate central value (arithmetic average) of geometric mean values for Hanford sediments representative of the saturated zone – either estimated, interpreted from aquifer tests or tracer tests, or calculated from lab tests on samples taken from within 5 m above the water table to the bottom of a specified borehole (Tables D-3 and D-17 in DOE/RL-2007-28).
	Ringold Formation member of Wooded Island - lower mud unit	0.3	Value used for 200-BP-5 and 200-PO-1 modeling, (Table 4-6 in ECF-HANFORD-13-0031). Estimated from Table 6.3 in PNNL-15239 where θ (total porosity) = 0.316 for sediment (Ringold lower mud unit) from borehole 299-W15-46, depth of 131 to 131.7 m with a total silt/clay content of 82.2% (36.7% clay).
Bulk Density	Hanford formation, Cold Creek unit	1.93 g/cm^3	Table 6.2 in PNNL-18564. Value is selected as representative of the Hanford formation gravel-dominated Cold Creek unit immediately overlying the upper Ringold Formation unit 4 (Figure 3-1 in CP-57037). According to PNNL-18564, the value represents the best professional judgment of technical experts/authors of reports cited in PNNL-18564, with the sediment class nomenclature qualitatively described in Table 6.2 as Hanford formation gravelly sand or sandy gravel.
	Ringold Formation member of Taylor Flat, Ringold Formation member of Wooded Island – unit E, Ringold Formation member of Wooded Island – lower mud unit, Ringold Formation member of Wooded Island – unit A	1.90 g/cm^3	Table 6.2 in PNNL-18564. Value is representative of the saturated Ringold Formation members typically comprising fluvial gravel, moderately to strongly cemented, and interstratified with finer-grained deposits. The values represent the reports cited in PNNL-18564, with the sediment class nomenclature qualitatively described in Table 6.2 as Rg-Ringold Formation sandy gravel. (Note: the well bedded fine-to-coarse sand to silt sediments of the Taylor Flat member are explicitly excluded from the ascribed qualitative description.)

Note: Complete reference citations are provided in Chapter 8 of this document.

4.2.2.2 Geochemical Properties

As contaminants flow through the groundwater, they interact with the soil particles depending on the nature of the contamination. The geochemical processes simulated as part of the fate and transport of contaminants include adsorption to the soil matrix and radioactive decay. Linear partitioning coefficients (K_d), half-lives, and decay rates were assigned based on field-specific data, and literature values (from Table 4-6 in DOE/RL-2018-69, *Cumulative Impact Evaluation Technical Approach Document*) are summarized in Table 4-6.

Table 4-6. Contaminant Transport Parameter Values

COC	K_d (mL/g)	Half-Life (yr)	Half-Life (day)	Degradation Rate (d^{-1})
I-129	0.1	15,700,000	5,370,000,000	0.000000000121

Note: Table is derived from Table 4-6 in DOE/RL-2018-69, *Cumulative Impact Evaluation Technical Approach Document*.

COC = contaminant of concern

K_d = partitioning coefficient

4.2.3 Hydrodynamic Dispersion

As contaminants move through the subsurface, plumes of contaminants tend to spread. This is caused by molecular diffusion based on concentration gradients and the interaction with soil particles through tortuous and variable paths called dispersivity. The total effect of these phenomena on the contaminant plume is referred to as hydrodynamic dispersion. Where flow of groundwater is relatively high, as within the saturated zone of the suprabasalt aquifer at the Hanford Site, the dispersivity component outweighs diffusion on impacts to the concentration. This renders the effect of the diffusion term on concentration negligible in the saturated zone. The input parameters and discussion related to selection of these values for this ECF are shown in Table 4-7.

Table 4-7. Transport Model Dispersivity Properties

Property	Value	Basis
Longitudinal dispersivity	50 m	Selected based on the smallest grid cell size (100 x 100 m) and to maintain a Peclet Number between 2 and 4 as recommended to maintain model stability (Campbell et al., 1980, and Zheng and Wang, 1999). The value of 50 m is also supported through sensitivity simulations completed and documented in ECF-HANFORD-21-0006.
Transverse dispersivity	10 m	20% of longitudinal. Transverse dispersivity is generally considered to be approximately an order of magnitude smaller than longitudinal dispersivity (Gelhar et al., 1992). A review of transverse Dispersivity in S-N/99205-103-REV1 indicates that, in general, transverse horizontal dispersivity is a factor of 3 to 30 less than longitudinal dispersivity.
Vertical dispersivity	2.5 m	Assigned to Hanford, Cold Creek, Ringold Taylor Flat, unit E, and unit A. Based on sensitivity simulations presented in ECF-HANFORD-21-0006. Lateral scales of transport and the dominance of horizontal flow in Central Plateau (DOE/RL-2007-28).

Table 4-7. Transport Model Dispersivity Properties

Property	Value	Basis
	0.0 m	Ringold Lower Mud - Simulation of no vertical dispersion in lower mud is based on the unit acting as a confining unit to the Ringold unit A below and the assumption that the contamination is not moving through the lower mud unit.
Molecular diffusion constant	0.0 m^2/d	Negligible term due to the comparatively large longitudinal and lateral scales of transport and predominance of advective flow.
Note: Complete reference citations are provided in Chapter 8 of this document.		

4.2.4 Continuing Sources

In the CIE, all waste sites within the P2R model extent were used in the Hydrocarbon Spill Screening Model package. However, for this ECF, only I-129 waste sites in the vicinity of the 200-UP-1 OU I-129 plume were included. A list of those sites is included in Table 4-8.

Table 4-8. Waste Sites Considered for Continuing Source Impact Evaluation

WIDS Site Name	Within 200-UP-1	Waste Form[a]	Volume Mean, ML (SIM-v2)[a]	I-129, Ci (SIM-v2)[a]	Vadose Zone Model Name in CIE[b]
216-S-7	Yes	Liquid	389.9	0.351	REDOX
216-U-10	Yes	Liquid	126776.6	0.214	U-10
216-S-1&2	Yes	Liquid	160.426	0.136	S FARMS
216-W-LWC	No (at northwest TI zone boundary)	Liquid	998.839	0.051	LW CRIB
216-S-9	Yes	Liquid	49.57951	0.029	U PLANT
216-U-14	Yes	Liquid	4884.095	0.0082	U FARMS
216-S-20	Yes	Liquid	135.4076	0.0081	REDOX
216-U-8	Yes	Liquid	375.4902	0.0049	U PLANT
216-S-6	Yes	Liquid	4440.147	0.0028	RSP
216-S-12	Yes	Liquid	0.074767	4.01E-04	REDOX
216-S-21	Yes	Liquid	87.137	3.27E-04	S FARMS
216-S-17	Yes	Liquid	6436.545	4.71E-05	RSP
UPR-200-W-61	Yes	Liquid	0.000924	3.53E-05	REDOX
216-S-16P	Yes	Liquid	40723.25	3.50E-05	RSP
216-S-5	Yes	Liquid	4084.911	3.18E-05	RSP
216-S-3	Yes	Liquid	4.202533	2.18E-05	S FARMS
216-S-10P	Yes	Liquid	6728.922	1.81E-05	RSP
216-S-22	Yes	Liquid	0.0983	6.39E-06	REDOX

Table 4-8. Waste Sites Considered for Continuing Source Impact Evaluation

WIDS Site Name	Within 200-UP-1	Waste Form[a]	Volume Mean, ML (SIM-v2)[a]	I-129, Ci (SIM-v2)[a]	Vadose Zone Model Name in CIE[b]
216-U-1&2	Yes	Liquid	15.929	2.27E-06	U PLANT
UPR-200-W-95	Yes	Liquid	3.97E-05	1.68E-06	REDOX
216-U-12	Yes	Liquid	148.9838	1.38E-06	U PLANT

a. ECF-HANFORD-17-0079, *Hanford Soil Inventory Model (SIM-v2) Calculated Radionuclide Inventory of Direct Liquid Discharges to Soil in the Hanford Site's 200 Areas*.

b. CP-63515, *Model Package Report: Central Plateau Vadose Zone Models*.

CIE = cumulative impact evaluation

LW = low level

ML = megaliter

REDOX = reduction oxidation

RSP = REDOX ponds area

WIDS = Waste Information Data System

4.2.5 Well Monitoring Network for 95%UCL

While existing monitoring wells in the 200-UP-1 OU and 200 East Area within the P2R model version 8.3 domain were used where available (DOE/RL-2015-14), several additional monitoring locations were chosen to fill gaps in the well coverage. These locations are referred to herein as "synthetic" wells. When expanding the network, attempts were made to maintain a reasonably uniform spatial distribution of monitoring locations along the expected path of the plume. Note, a set of four synthetic wells (ZP-1_17, UP-1_2, UP-1_3, and UP-1_4) were added to keep track of the plume as it migrates toward the east of the model domain (Figure 4-6.).

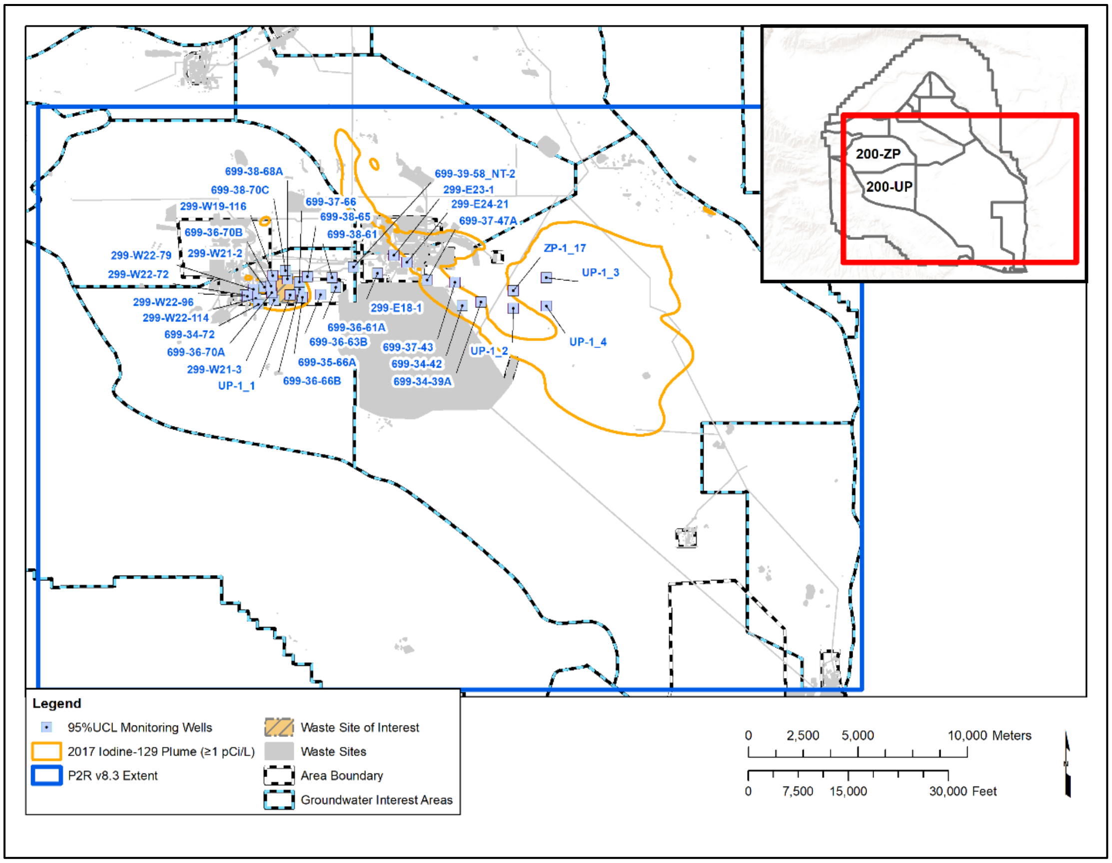

Figure 4-6. Monitoring Well Network for the 95%UCL Calculation

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5 Software Applications

MODFLOW-2000-MST and MT3DMS-MST, Microsoft® Excel® and ArcGIS® software programs were used for this ECF. These are Central Plateau Cleanup Company (CPCCo) approved software, managed and used in compliance with the requirements of CPCC-PRO-IRM-309, *Controlled Software Management*. MODFLOW-2000-MST and MT3DMS-MST are approved calculation software, and Microsoft Excel and ArcGIS is approved support software (CP-66776, *MODFLOW and Related Codes Software Management Plan*). The following supporting information is provided.

5.1 Approved Software

MODFLOW-2000-MST and MT3DMS-MST were executed on the INTERA Richland OLIVE Linux® Cluster that is owned and managed by INTERA, Inc., a preselected subcontractor to CPCCo. The computer property tag for the front-end node is #825 at INTERA's office in Richland, Washington. This node is a Dell® PowerEdge® R530 Server with 12 Intel® Xeon® E5-2680 v3 CPU (x2) Cores (48 processors) @ 2.5 GHz with 30 MB Cache and 128 GB of RAM. The workstation storage consists of 26 TB RAID-5 disk array. As given by the command "uname –a", the operating system details are as follows:

```
Linux olive 4.4.0-38-generic #57~14.04.1-Ubuntu SMP Tue Sep 6 17:20:43 UTC
2016 x86_64 x86_64 x86_64 GNU/Linux
```

For approved software used in this ECF, the required descriptions are provided in the following section.

5.1.1 Description

MODFLOW

- **Software Title:** MODFLOW-2000-MST
- **Software Version:** CHPRC Build 8 (executable file "mf2k-mst-chprc08dpl.x")
- **Hanford Information System Inventory (HISI) Identification Number:** 2517 (Safety Software, Level C)
- **CPCCo Software Control Documents:**
  - CP-66810, *MODFLOW and Related Codes: Build 9 Software Requirements Specification Report*
  - CP-66776, *MODFLOW and Related Codes: Build 9 Software Management Plan*
  - CP-66777, *MODFLOW and Related Codes: Build 9 Software Test Plan*
  - CP-66811, *MODFLOW and Related Codes: Build 9 Requirements Traceability Matrix*
  - CP-66778, *MODFLOW and Related Codes: Build 9 Software Acceptance Test Report*

MT3DMS-MST

- **Software Title:** MT3DMS-MST
- **Software Version:** CHPRC Build 8 (executable file "mt3d-mst-chprc08dpl.x")

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® ArcGIS is a registered trademark of ESRI in the United States and other countries.

® Linux is the registered trademark of Linus Torvalds (individual), Boston, Massachusetts.

® Dell and PowerEdge are registered trademarks of Dell Corporation, Round Rock, Texas.

® Intel and Zeon are registered trademarks of Intel Corporation, Santa Clara, California.

- **HISI Identification Number:** 2518 (Safety Software, Level C)
- **CPCCo Software Control Documents:**
  - CP-66810
  - CP-66776
  - CP-66777
  - CP-66811
  - CP-66778

5.1.2 Software Installation and Checkout

The approved safety software packages (MODFLOW, MT3DMS) were checked out in accordance with procedures specified in CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*. Executable files were obtained from the software owner who maintains the configuration-managed copies in Azure DevOps® installation tests identified in CHPRC-00259, *MODFLOW and Related Codes Software Test Plan* were performed, and successful installation confirmed. Software Installation and Checkout Forms were completed and approved for installations used to perform model runs reported in this calculation. A copy of the Software Installation and Checkout Form for this controlled use software is provided in Attachment A of this ECF.

5.1.3 Statement of Valid Software Application

The preparer of this calculation brief attests that the software identified above and used for the calculations described in this calculation brief, are appropriate for the application and used within the range of intended uses for which they were tested and accepted by CPCCo.

Because MODFLOW and MT3DMS are graded as Level C software, use of these software programs is required to be logged in the HISI. Accordingly, this environmental calculation has been logged by the software owner in the HISI under Identification Numbers 2517 and 2518, respectively.

® Azure DevOps is a registered trademark of the Microsoft Corporation in the United States and in other countries.

6 Calculation

The following flow and transport scenarios (Table 6-1) were calculated using MODFLOW and MT3DMS, respectively. In addition to Scenarios 1 and 2, a sensitivity case, Scenario 3, with no continuing source was simulated to evaluate the model output if the continuing source is not going to contribute to the aquifer at or above 1 pCi/L. Concentration data contained in the Transport Observation Package output file was used to calculate the 95%UCL mean concentration in Rwie. The output MT3DMS concentration file was used to generate plume maps over time and to calculate maximum concentration of all the layers in the aquifer.

Table 6-1. Flow and Transport Scenarios

Scenario	Pumping	Continuing Source
1	I-129 injection wells end in 2037	Yes
2	I-129 injection wells end in 2020	Yes
3 (Sensitivity Case)	I-129 injection wells end in 2020	No

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7 Results/Conclusions

Table 6-1 shows the flow and transport scenarios performed for this analysis. Scenarios 1 and 2 included a continuing source, while Scenario 3 did not. Scenario 1 included I-129 injection well operation through 2037, while Scenarios 2 and 3 modeled I-129 injection wells ceasing operation in 2020.

Scenarios 1 and 2 were compared using 95%UCL mean concentration timeseries, plume maps at relevant times, and timeseries plots of maximum concentration in the entire aquifer. Figure 7-1, Figure 7-2, and Figure 7-3 show the plume extent at specified times for Scenario 1. Figure 7-6, Figure 7-7, and Figure 7-8 show the plume extent for the same times for Scenario 2, and Figure 7-11, Figure 7-12, and Figure 7-13 show the plume extent for the same times for Scenario 3. The plume spatial extent and migration rates and direction are similar for both Scenarios 1 and 2 at corresponding times.

Figure 7-4, Figure 7-9, and Figure 7-14 show the maximum aerial extent of the 200-UP-1 OU plumes in Scenarios 1, 2, and 3, respectively. Comparison of Scenarios 1 and 2 show that the extent of plumes is similar for corresponding times.

Figure 7-5, Figure 7-10, and Figure 7-15 show the timeseries plots of 95%UCL and Cmax for the entire aquifer for Scenarios 1, 2 and 3, respectively. The 95%UCL computation was discussed in Section 3.2. The Cmax timeseries were computed by determining the maximum concentration in any cell (in any layer) within the aquifer represented in the model domain. Cleanup times based on the 95%UCL and Cmax series are determined from when each series falls below the cleanup level of 1 pCi/L, shown on the graphs. Table 7-1 summarizes the cleanup times for each scenario based on 95%UCL and Cmax.

The spatial extents of the plumes, maximum plume extents, 95%UCL and Cmax results show that the impact of injection cessation in 2020 rather than 2037 (Scenarios 2 and 1, respectively) has minimal or no impact on either the maximum ultimate extent or the cleanup time for the 200-UP-1 OU plume in Scenarios 1 and 2. The maximum plume extents from ceasing injection in 2020 versus 2037 predicts the same maximum area of 4.7 km^2, and that the maximum extent happens 227 years after the model start of 01/01/2018 (compare Figure 7-2 and Figure 7-7, bottom left). The cleanup times predicted by the 95%UCL and Cmax analyses in Scenarios 1 and 2 are equivalent (see Table 7-1).

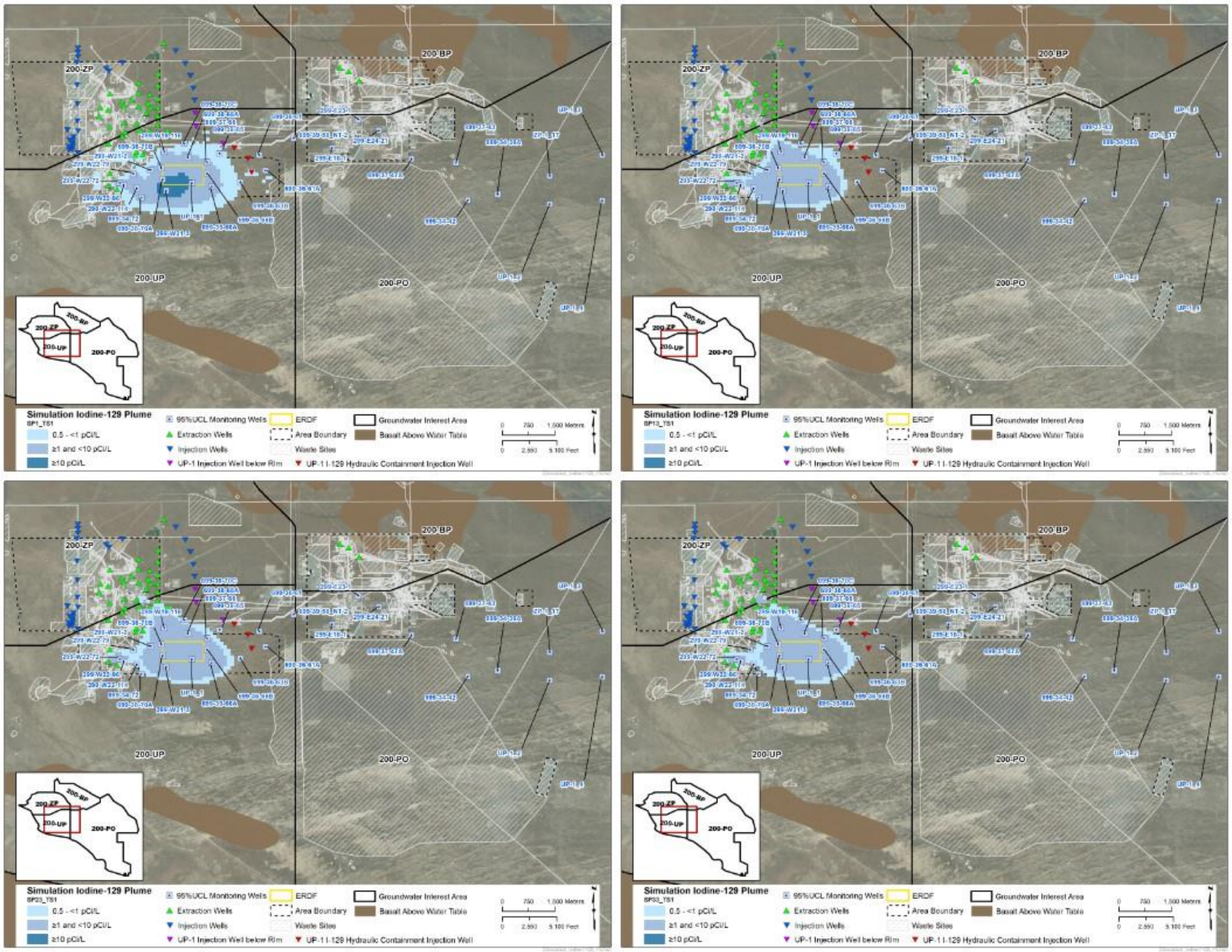

Figure 7-1. Simulation Results for the 200-UP-1 OU, Scenario 1, Showing the Maximum of All Layers for Years 1 and 13 (top left and right), and Years 23 and 33 (bottom left and right)

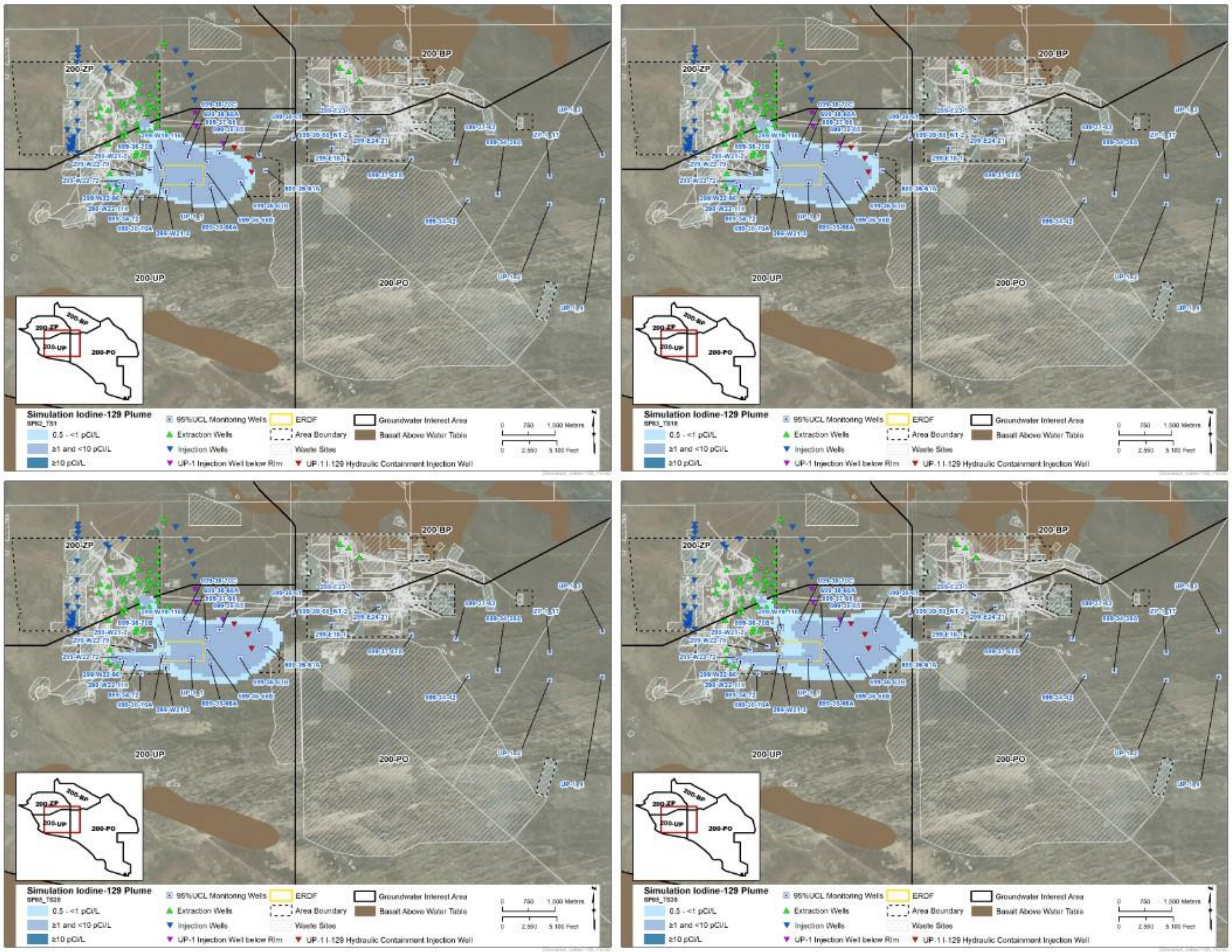

Figure 7-2. Simulation Results for the 200-UP-1 OU, Scenario 1, Showing the Maximum of All Layers for Years 82 and 117 (top left and right), and Years 227 and 302 (bottom left and right)

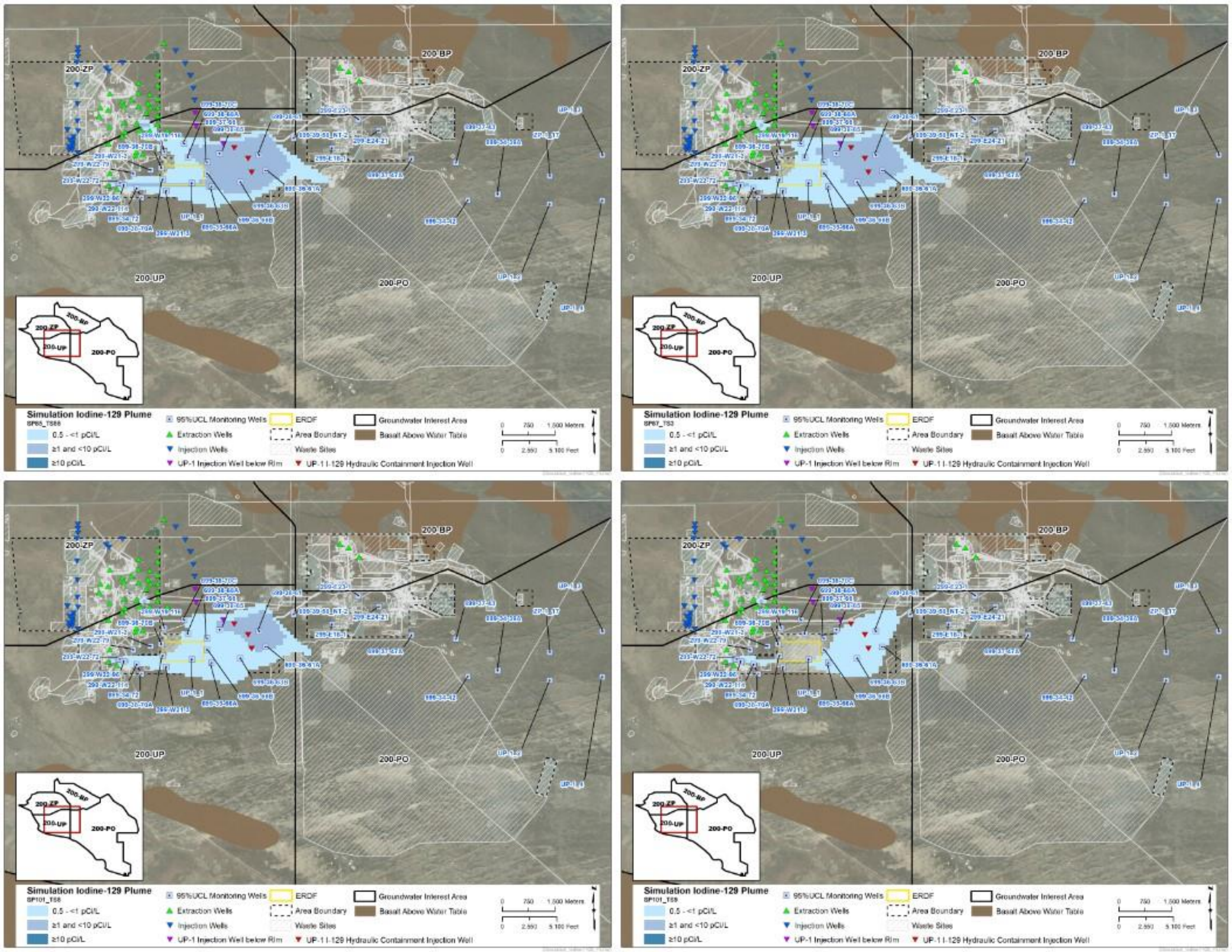

Figure 7-3. Simulation Results for the 200-UP-1 OU, Scenario 1, Showing the Maximum of All Layers for Years 402 and 502 (top left and right), and Year 602 and 1053 (bottom left)

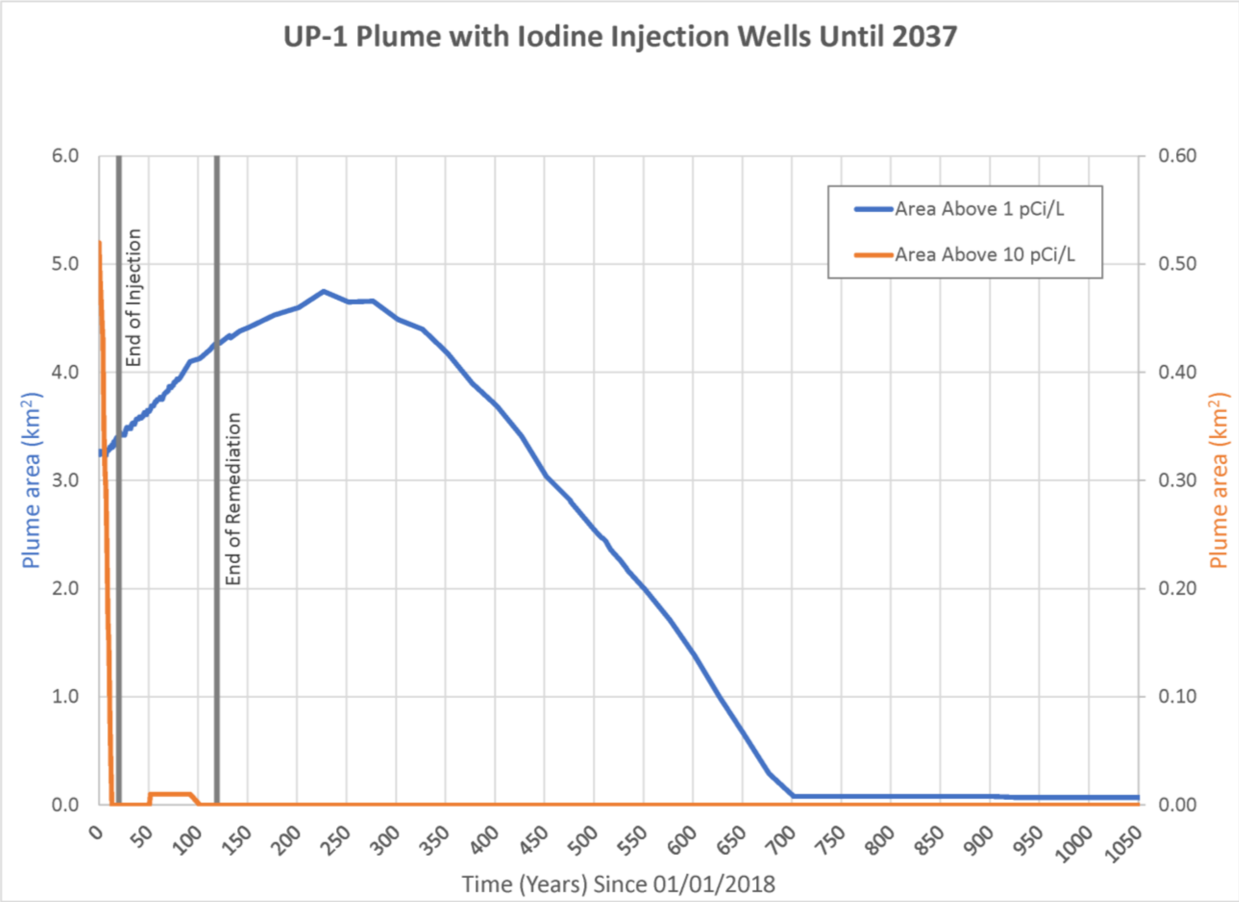

Figure 7-4. Maximum Extent of the 200-UP-1 OU Plume in Scenario 1

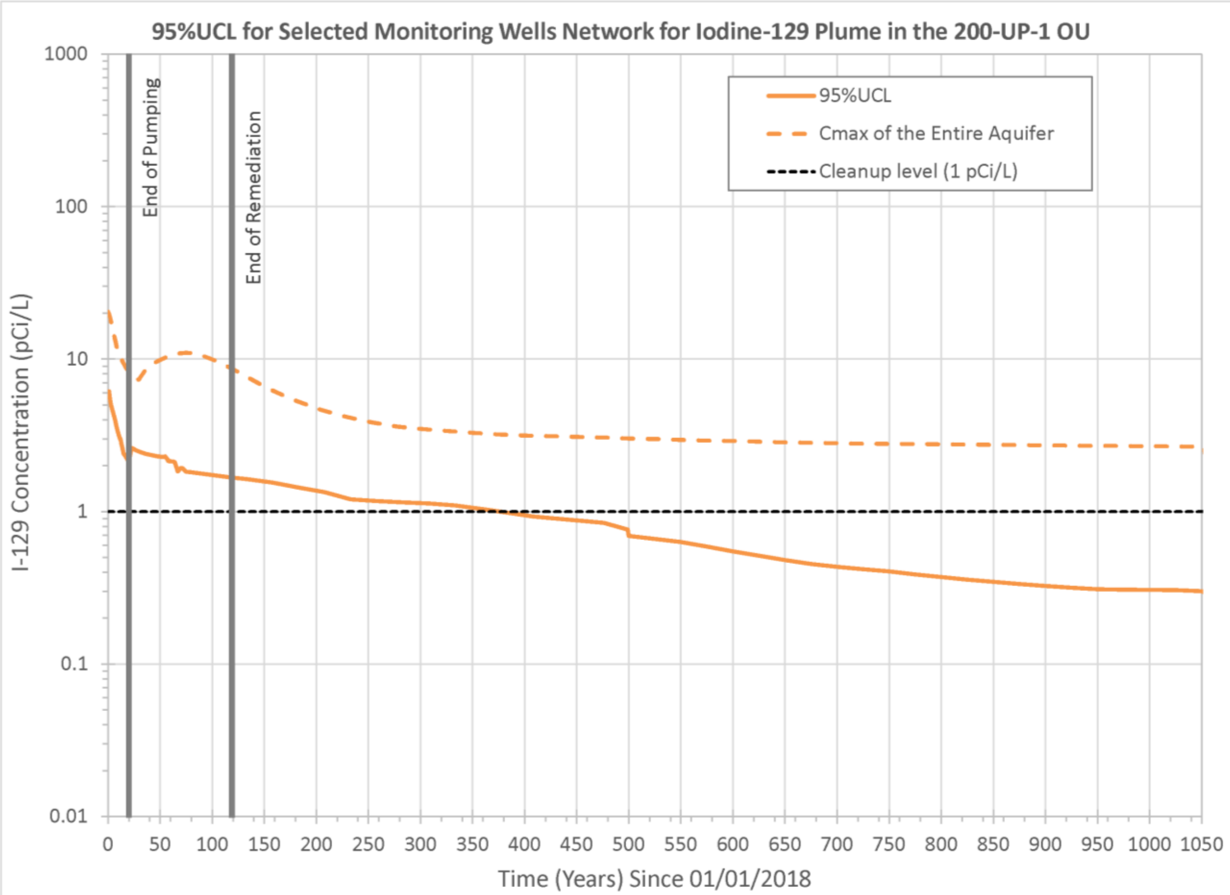

Figure 7-5. Timeseries Plot of 95%UCL for Selected Monitoring Wells Network Compared to Cmax of the Entire Aquifer for Scenario 1

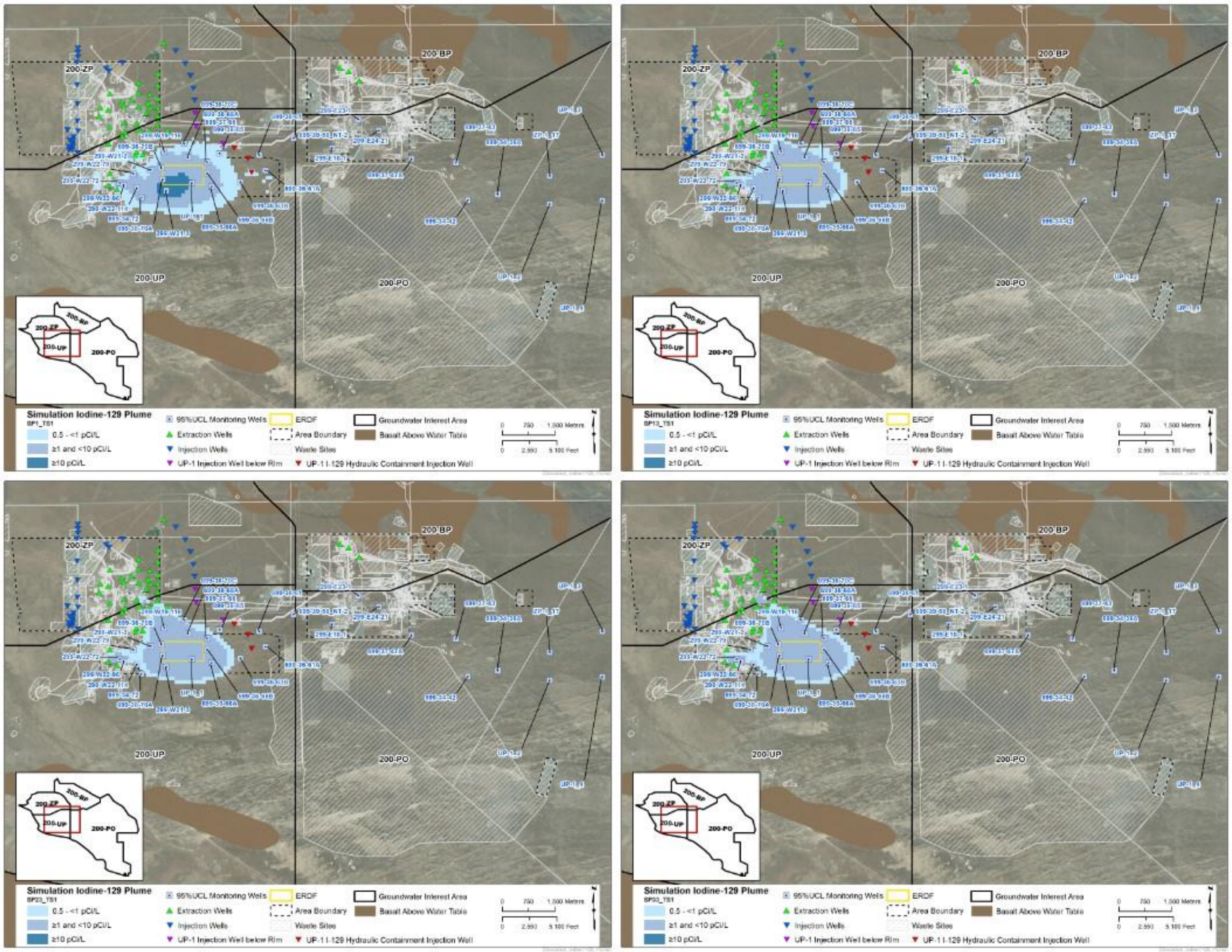

Figure 7-6. Simulation Results for the 200-UP-1 OU, Scenario 2, Showing the Maximum of All Layers for Years 1 and 13 (top left and right), and Years 23 and 33 (bottom left and right)

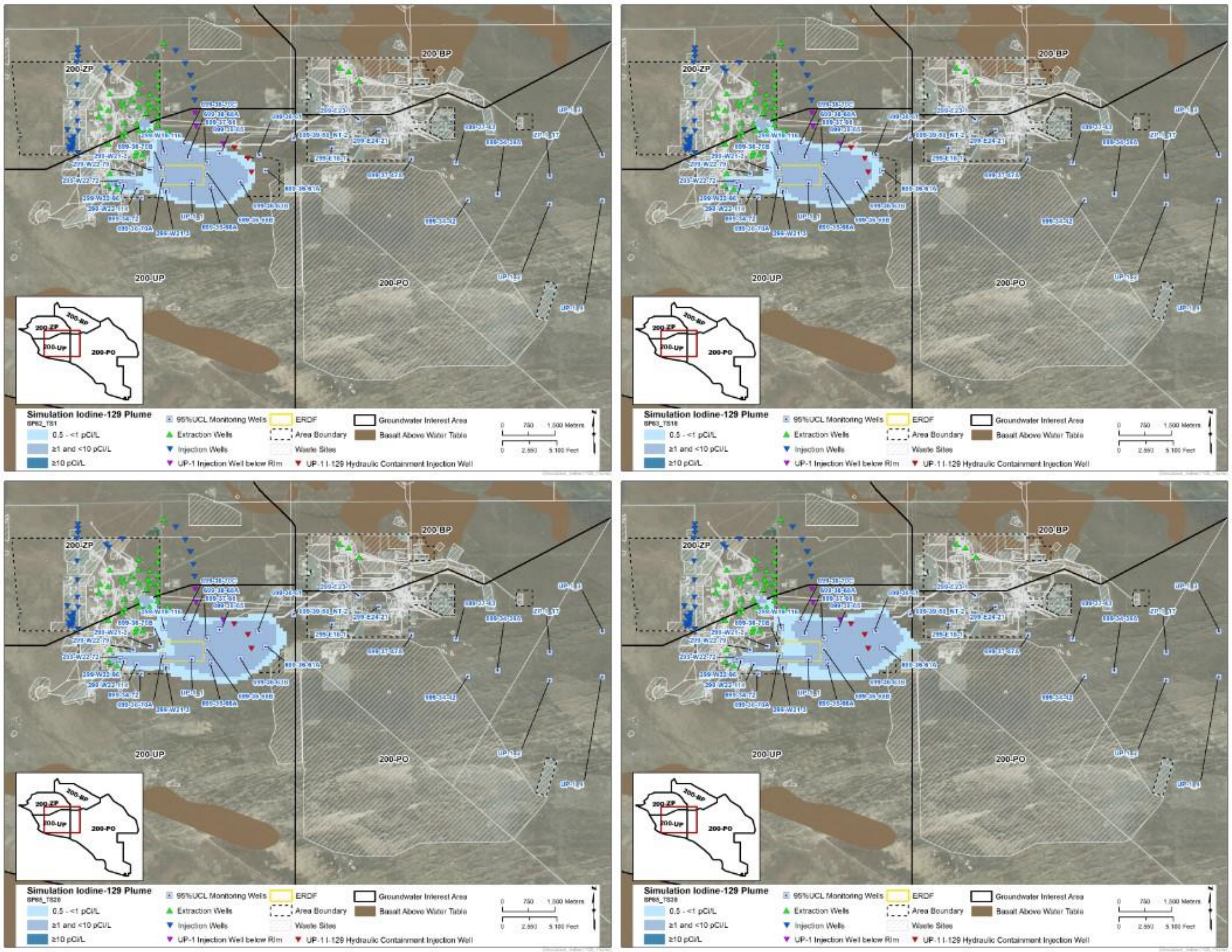

Figure 7-7. Simulation Results for the 200-UP-1 OU, Scenario 2, Showing the Maximum of All Layers for Years 82 and 117 (top left and right), and Years 227 and 302 (bottom left and right)

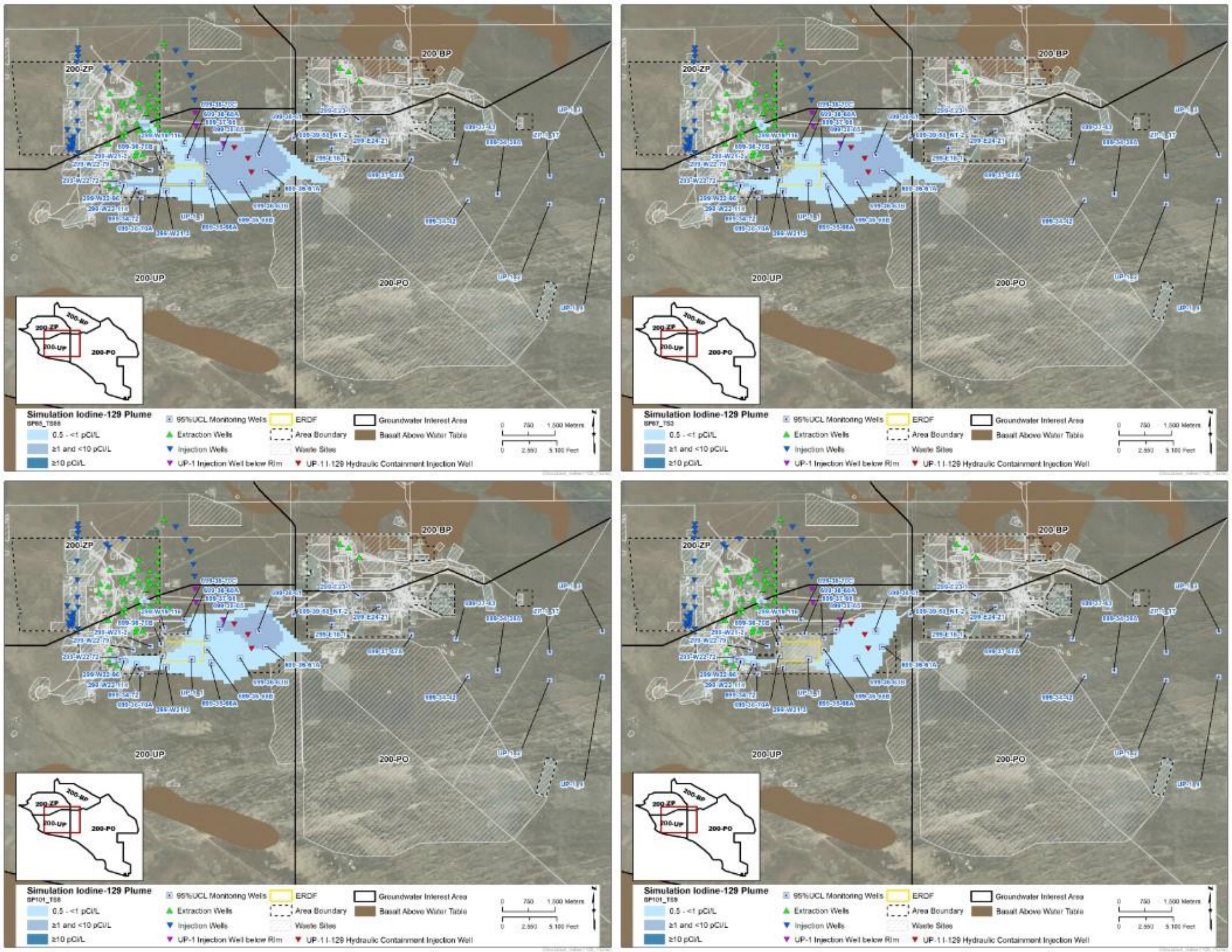

Figure 7-8. Simulation Results for the 200-UP-1 OU, Scenario 2, Showing the Maximum of All Layers for Years 402 and 502 (top left and right), and Year 602 and 1053 (bottom left)

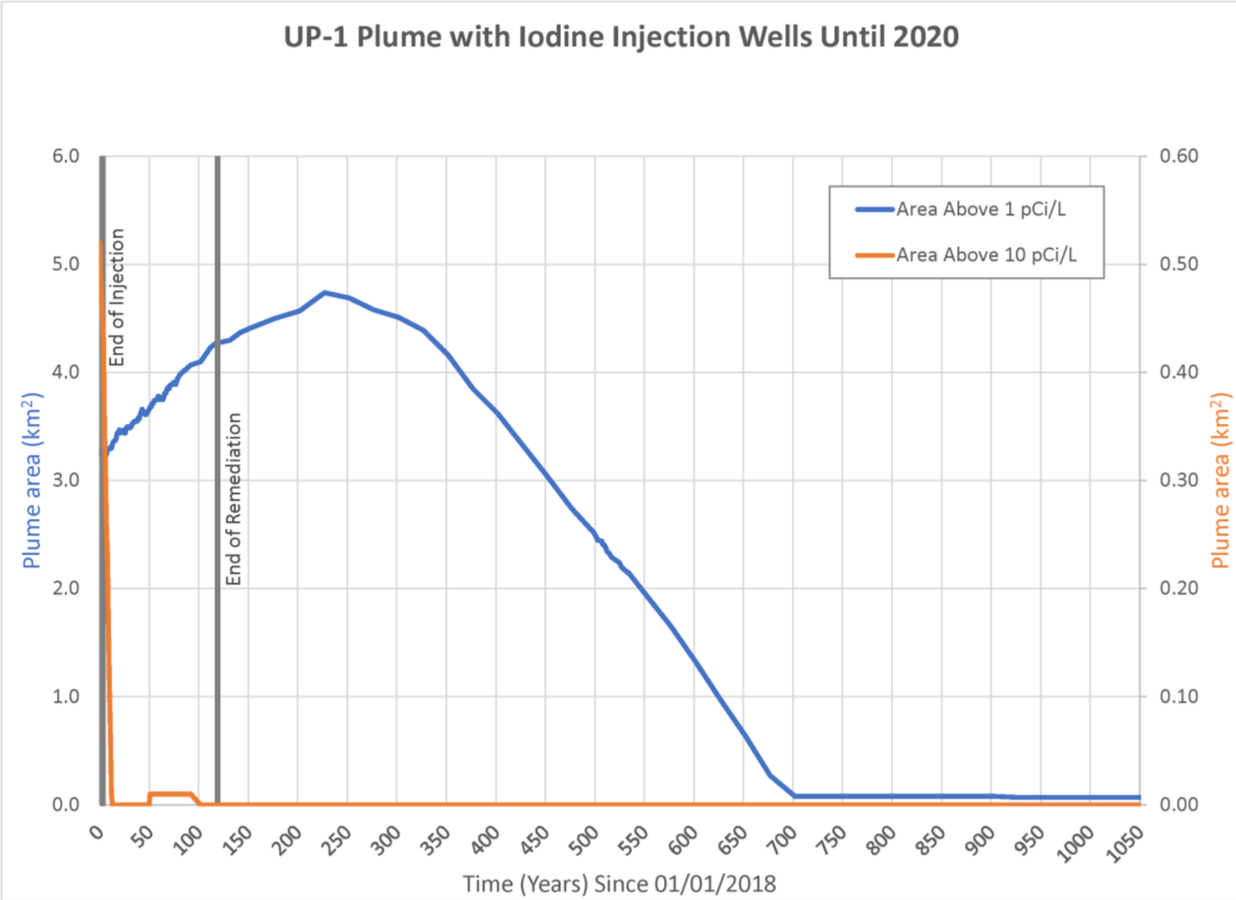

Figure 7-9. Maximum Plume Extent of the 200-UP-1 OU Plume in Scenario 2

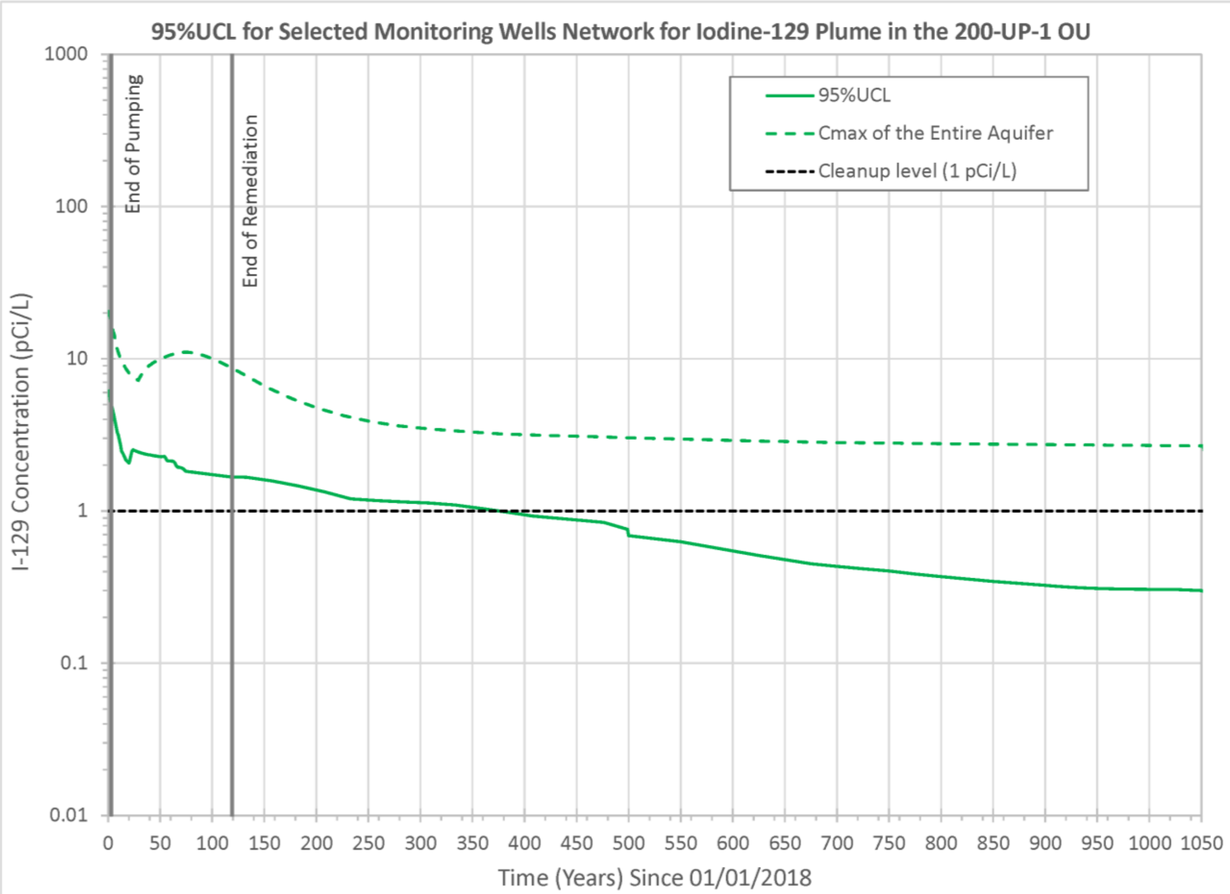

Figure 7-10. Timeseries Plot of 95%UCL for Selected Monitoring Wells Network Compared to the Cmax of the Entire Aquifer for Scenario 2

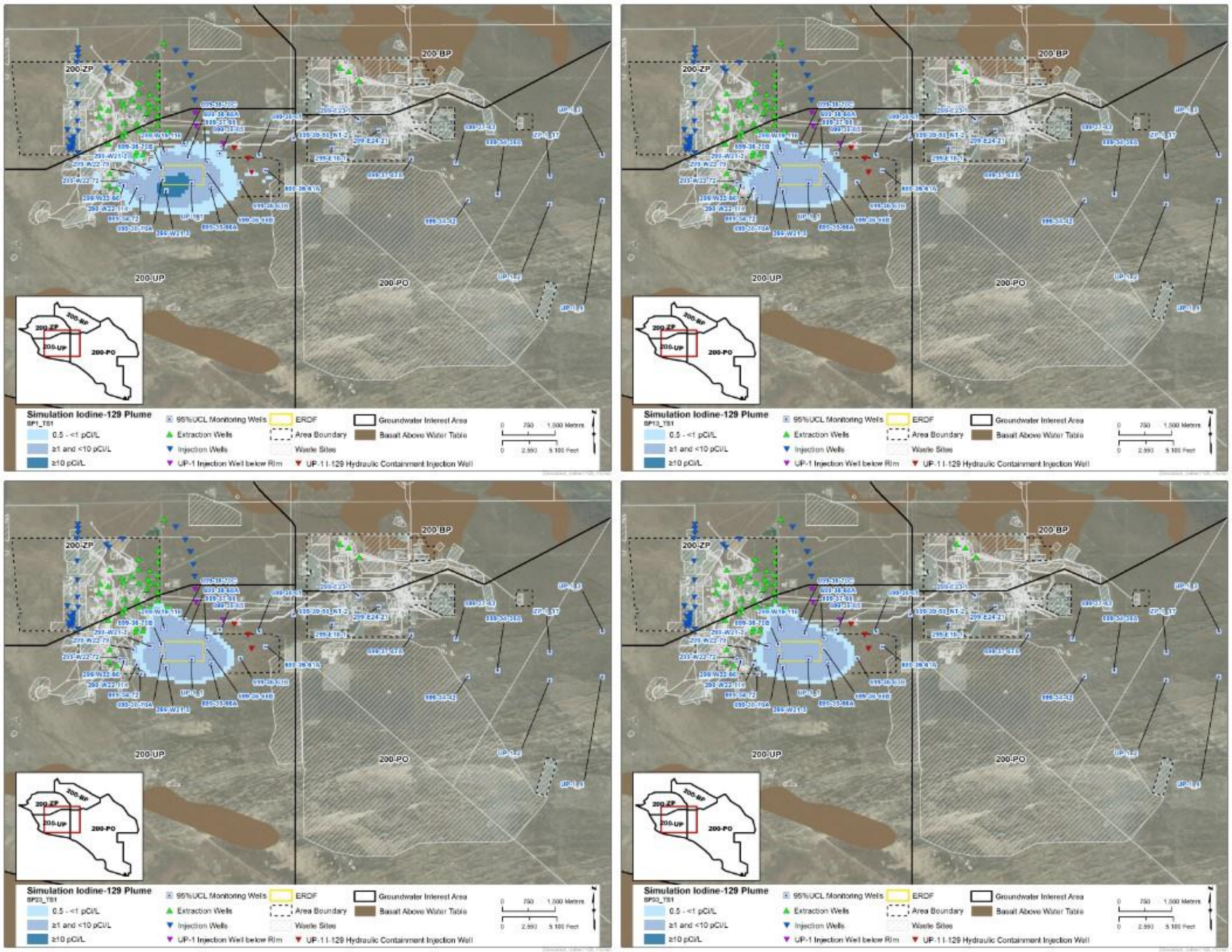

Figure 7-11. Simulation Results for the 200-UP-1, Scenario 3, Showing the Maximum of All Layers for Years 1 and 13 (top left and right), and Years 23 and 33 (bottom left and right)

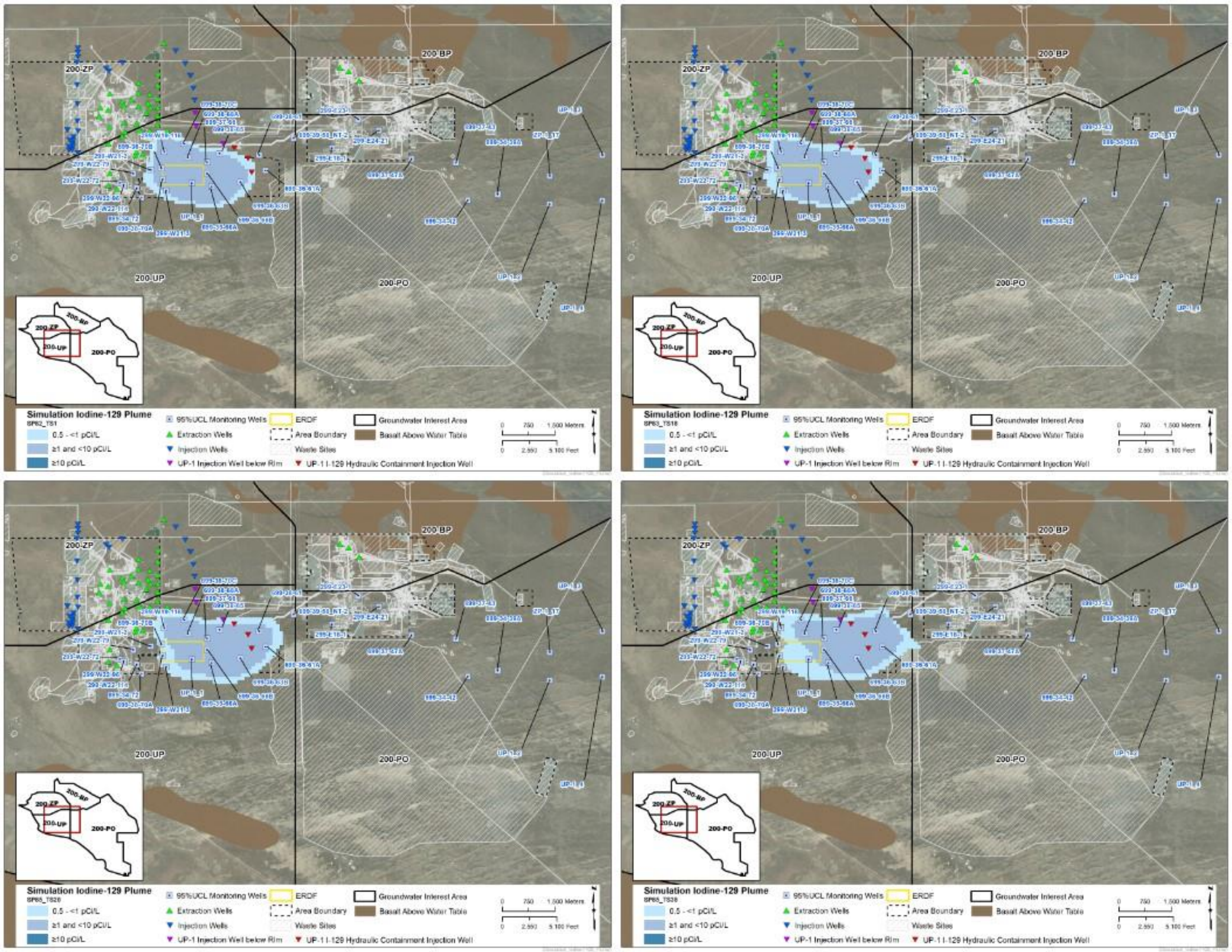

Figure 7-12. Simulation Results for the 200-UP-1 OU, Scenario 3, Showing the Maximum of All Layers for Years 82 and 117 (top left and right), and Years 227 and 302 (bottom left and right)

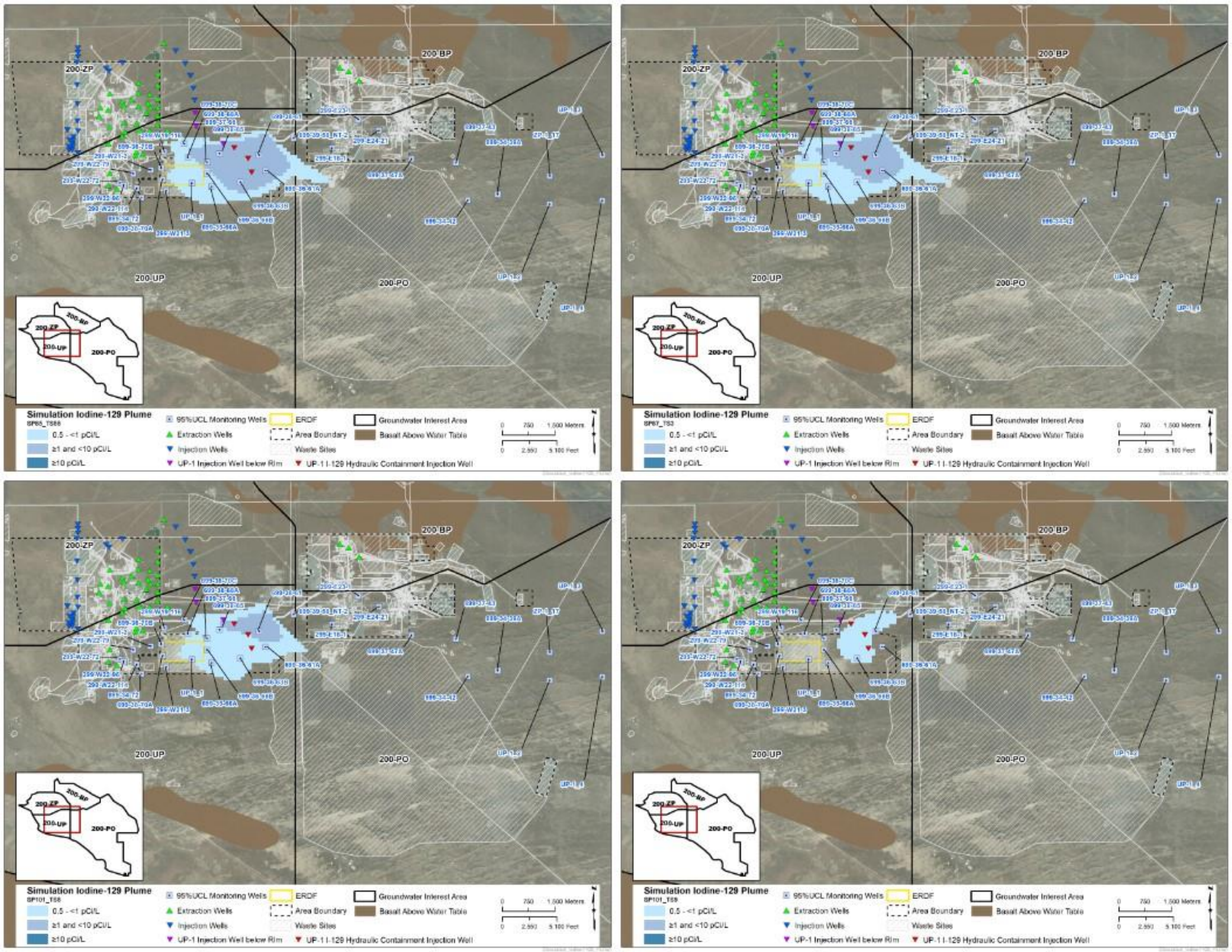

Figure 7-13. Simulation Results for the 200-UP-1 OU, Scenario 3, Showing the Maximum of All Layers for Years 402 and 502 (top left and right), and Year 602 and 1053 (bottom left)

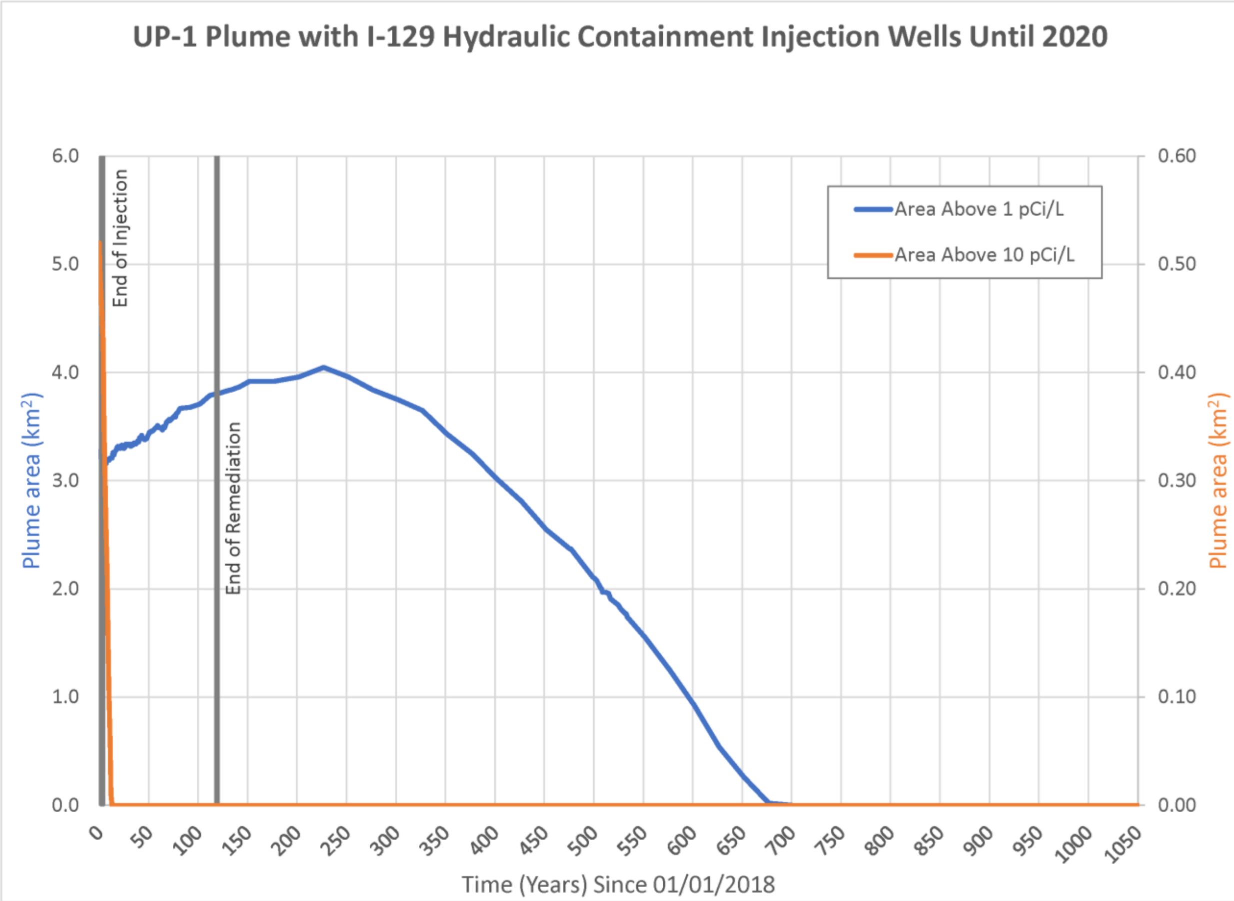

Figure 7-14. Maximum Plume Extent of the 200-UP-1 OU Plume in Scenario 3

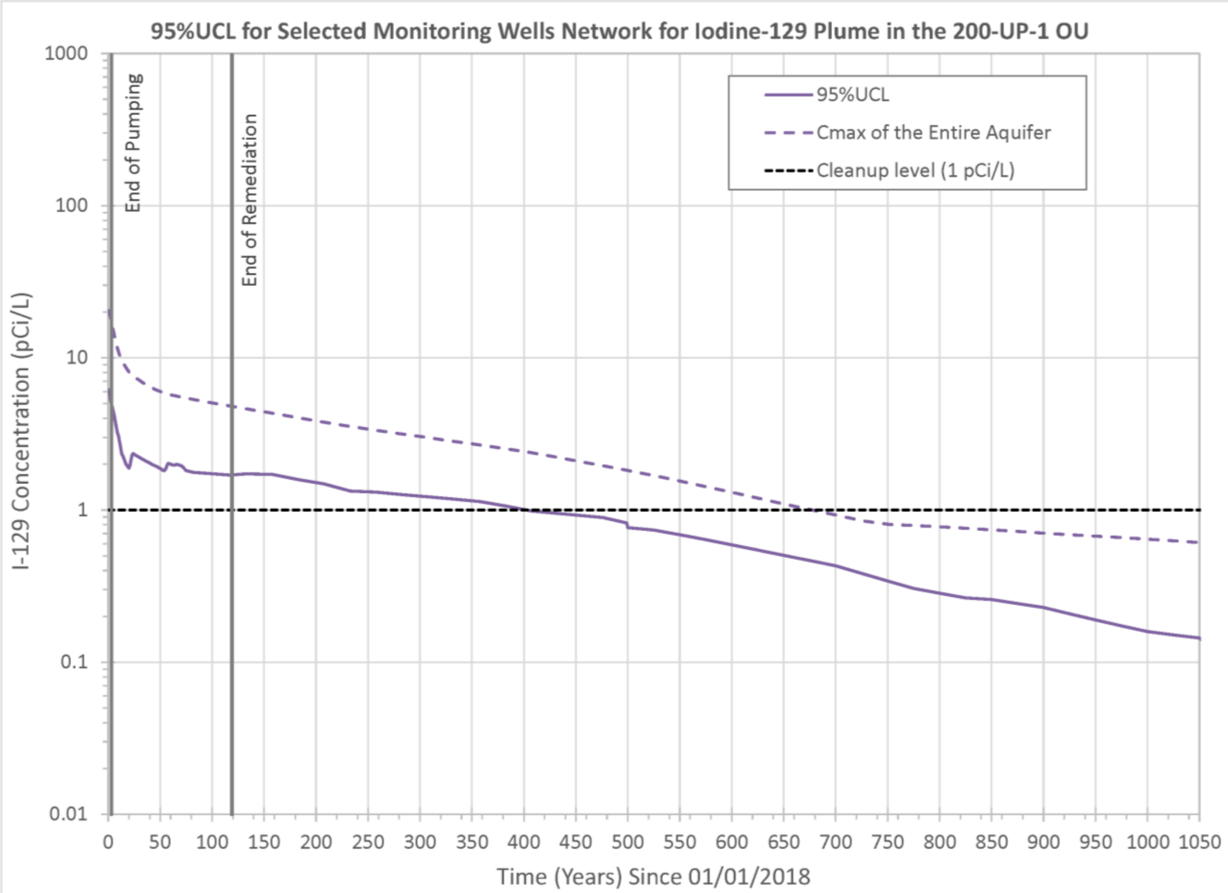

Figure 7-15. Timeseries Plot of 95%UCL for Selected Monitoring Wells Network Compared to the Cmax of the Entire Aquifer for Scenario 3

Table 7-1. Cleanup Time Based on 95%UCL and Cmax in Model Years Since 01/01/2018 for the 200-UP-1 OU

Scenario	95%UCL	Cmax
1	383	>1053
2	383	>1053
3 (Sensitivity Case)	408	702

7.1 Technical Impracticability Zone Boundary Determination

A TI zone boundary extent was investigated based on the maximum aerial extents of the 0.5 and 1.0 pCi/L concentrations of the I-129 plume throughout the entire model time period, using a geographic information system approach.

The TI zone boundary analysis process included the following steps:

1. For each transport model output time, the aerial extent of the 0.5 and 1 pCi/L was determined.
2. A 500 m buffer was applied to the 0.5 pCi/L aerial extent polygon.
3. A 50 m buffer was applied to the 1 pCi/L aerial extent polygon.
4. A single buffer was created from the two buffers, by choosing the greater of the two extents.
5. The resulting buffer was modified in places where the P2R model cells were evident, creating a straight line where there were stair-stepped areas.

After comparing the TI zone boundaries created for Scenarios 1 and 2, it was found that operation of I-129 injection wells until 2037 has no impact on the overall plume migration over 1053 years. As a result, the TI zone boundary for Scenarios 1 and 2 are essentially the same. The TI zone boundary extent chosen for use in the rest of this ECF is the one based on Scenario 2. The aerial extents of the TI zone boundary analyses for Scenario 2 and Scenario 3 (continuing source and no continuing source, respectively) are included in Figure 7-16 and Figure 7-17, as a comparison of the effect of continuing sources on the evaluation. Scenario 3 has a smaller TI zone boundary footprint than Scenario 2 due to the impact of the I-129 continuing sources.

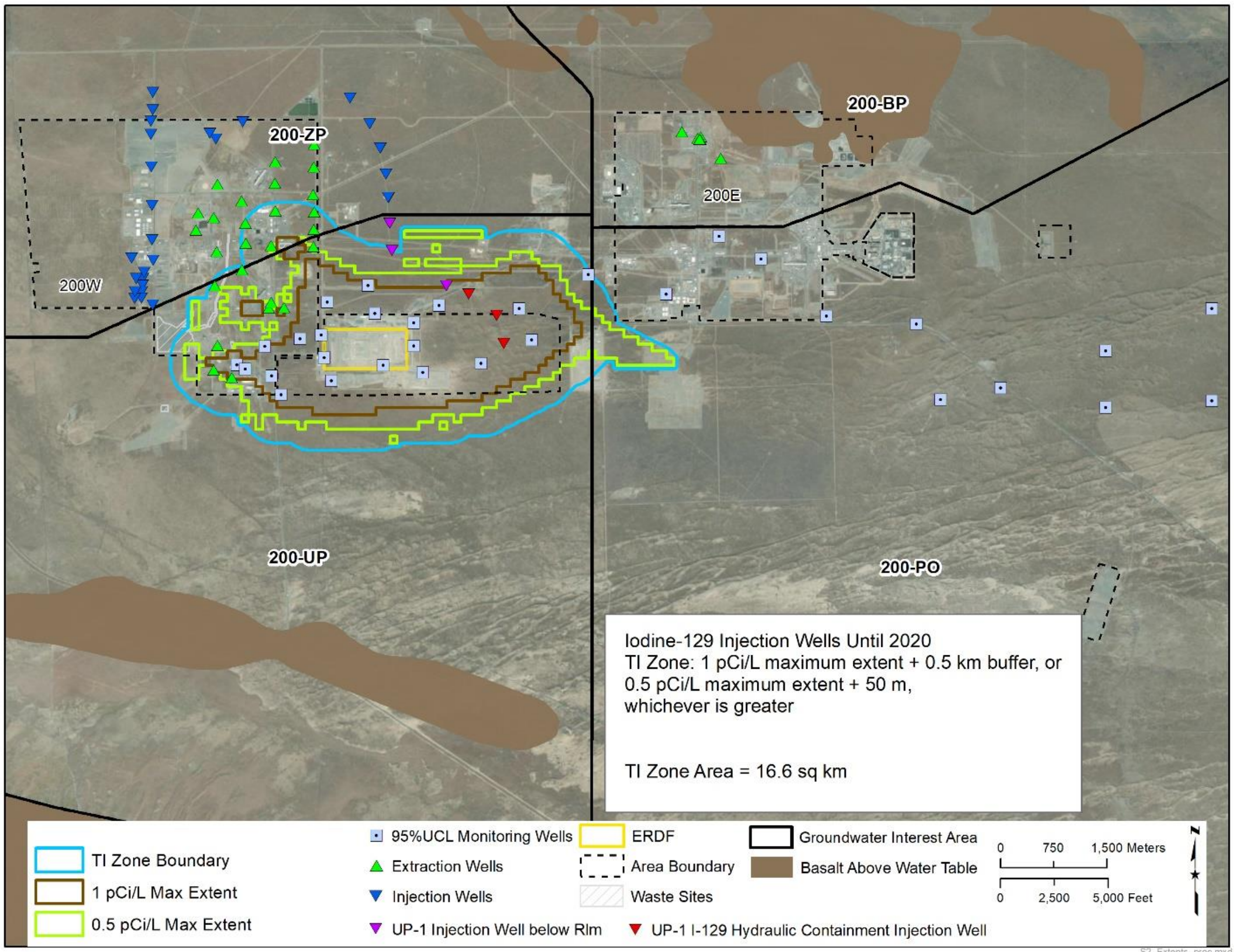

Figure 7-16. Concentration Boundaries Used to Analyze the Technical Impracticability Boundary Based on Scenario 2 (includes continuing sources)

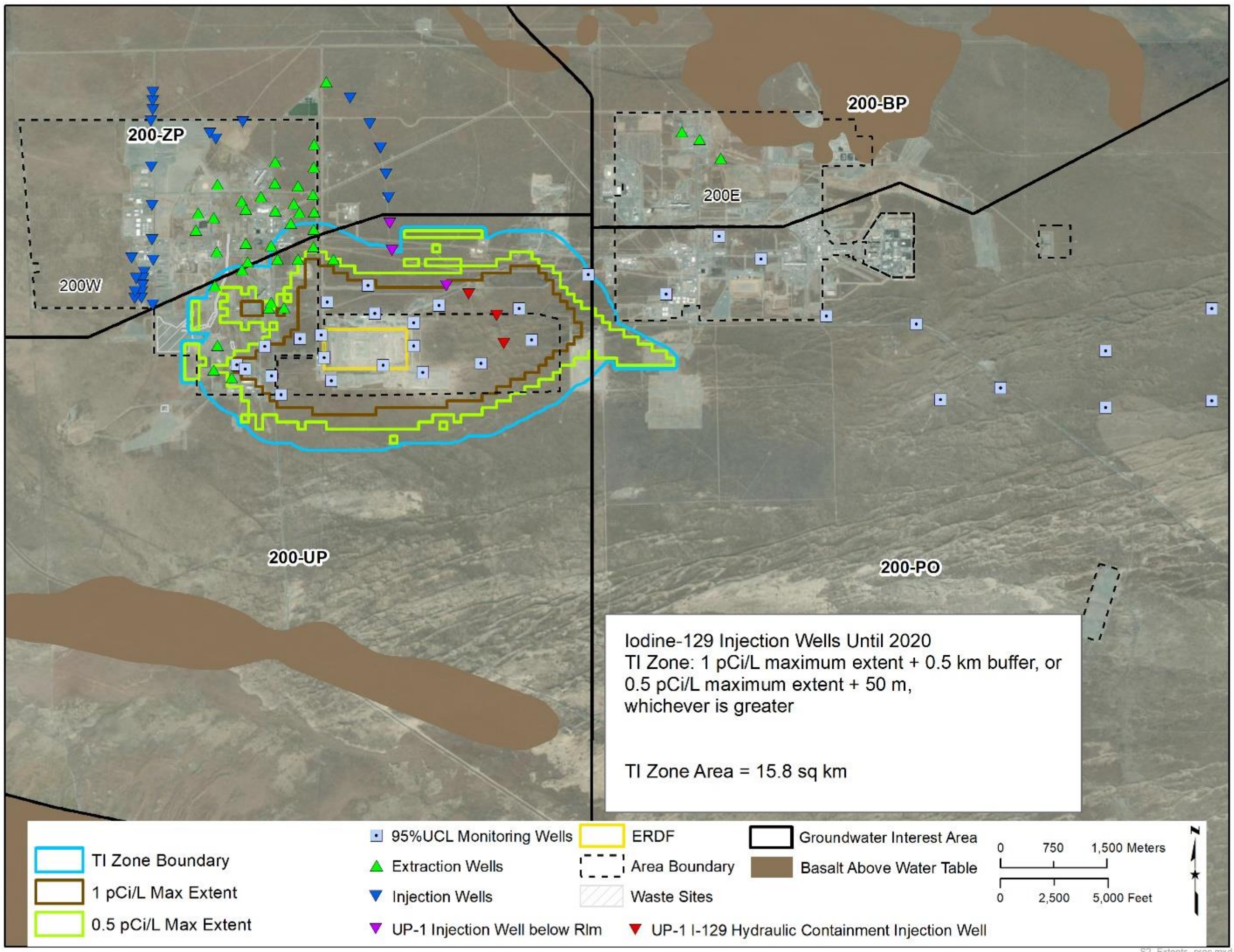

Figure 7-17. Concentration Boundaries Used to Analyze the TI Boundary based on Scenario 3 (with no continuing sources)

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8 References

Campbell, J.E., D.E. Longsine, M. Reeves, 1980, *Risk Methodology for Geologic Disposal of Radioactive Waste: The Distributed Velocity Method of Solving the Convective-Dispersion Equation*, Sandia National Laboratories, Albuquerque, New Mexico.

CHPRC-00258, 2015, *MODFLOW and Related Codes Software Management Plan*, Rev. 4, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0911120137.

CHPRC-00259, 2014, *MODFLOW and Related Codes Software Test Plan*, Rev. 3, CH2M HILL Plateau Remediation Company, Richland, Washington.

CP-57037, 2020, *Model Package Report: Plateau to River Groundwater Model Version 8.3*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03674.

CP-63515, 2020, *Model Package Report: Central Plateau Vadose Zone Models*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1714362.

CP-66776, 2022, *MODFLOW and Related Codes: Build 9 Software Management Plan*, Rev. 0, Central Plateau Cleanup Company, Richland Washington.

CP-66777, 2022, *MODFLOW and Related Codes: Build 9 Software Test Plan*, Rev. 0, Central Plateau Cleanup Company, Richland Washington.

CP-66810, 2022, *MODFLOW and Related Codes: Build 9 Software Requirements Specification Report*, Rev. 0, Central Plateau Cleanup Company, Richland Washington.

CP-66811, 2022, *MODFLOW and Related Codes*: *Build 9 Requirements Traceability Matrix*, Rev. 0, Central Plateau Cleanup Company, Richland Washington.

CP-66778, 2022, *MODFLOW and Related Codes Build 9 Software Acceptance Test Report*, Rev. 0, Central Plateau Cleanup Company, Richland Washington.

CPCC-PRO-IRM-309, *Controlled Software Management*, Central Plateau Cleanup Company, Richland, Washington.

DOE/RL-2007-28, 2008, *Feasibility Study Report for 200-ZP-1 Groundwater OU*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0808050315. https://pdw.hanford.gov/document/00098828.

DOE/RL-2013-07, 2013, *200-UP-1 Groundwater Operable Unit Remedial Design / Remedial Action Work Plan*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0087671.

DOE/RL-2014-32, 2014, *Hanford Site Groundwater Monitoring Report for 2013*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0084842.

DOE/RL-2015-14, 2015, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*, Draft A, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0079503H.

DOE/RL-2017-66, 2018, *Hanford Site Groundwater Monitoring Report for 2017*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://higrv.hanford.gov/Hanford_Reports_2017/Hanford_GW_Report/.

DOE/RL-2018-69, 2020, *Cumulative Impact Evaluation Technical Approach Document*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-04154.

ECF-200UP1-14-0019, 2014, *Initial Groundwater Plume Development (Uranium, Technetium-99, Nitrate, and Iodine-129) to Support Fate and Transport Modeling for Remedial Design in the 200 UP-1 Groundwater Operable Unit*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0064368H.

ECF-200UP1-14-0052, 2014, *Local-Scale Simulation of Iodine-129 Plume Containment for the Proposed Injection Wells at the 200-UP-1 Operable Unit*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0066446H.

ECF-200UP1-14-0053, 2015, *Containment System for 200-UP-1 Iodine*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0066445H.

ECF-200ZP1-19-0103, 2019, *Extraction Well Location and Rate Optimization in Support of the 200-ZP-1 Optimization Test Plan*, pending, Central Plateau Cleanup Company, Richland, Washington.

ECF-HANFORD-13-0031, 2015, *Fate and Transport Modeling for Baseline Conditions for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0080142H.

ECF-HANFORD-15-0019, 2020, *Hanford Site-wide Natural Recharge Boundary Condition for Groundwater Models*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-HANFORD-17-0079, 2018, *Hanford Soil Inventory Model (SIM-v2) Calculated Radionuclide Inventory of Direct Liquid Discharges to Soil in the Hanford Site's 200 Areas*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://www.osti.gov/biblio/1441375.

ECF-HANFORD-19-0093, 2020, *Development of Saturated Zone, Three-Dimensional Initial Condition Plumes for the Composite Analysis and Cumulative Impacts Evaluation Modeling Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-HANFORD-20-0049, 2020, *Description of Groundwater Calculations to Support Performance Assessment for the Calendar Year 2019 (CY 2019) 200 Areas Pump-and-Treat Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-04153.

ECF-HANFORD-20-0062, 2020, *Mapping the Concentration Distribution of Contaminant Plumes to the Computational Grid of the Plateau to River Model Version 8.3*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1635525.

ECF-HANFORD-21-0004, 2020, *Predictive Flow Simulation with the P2R Model for the Cumulative Impact Evaluation No Further Action Scenario*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1668408.

ECF-HANFORD-21-0005, 2021, *Predictive Contaminant Transport Simulation with the P2R Model for the Cumulative Impact Evaluation No Further Action Scenario*, Rev. 0, Central Plateau Cleanup Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-19051.

ECF-HANFORD-21-0006, 2021, *Alternative Conceptual Model near 200 East for the Plateau to River Model: Version 8.3.1*, Rev. 0, Central Plateau Cleanup Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-20021.

EPA, Ecology, and DOE, 2012, *Record of Decision for Interim Remedial Action Hanford 200 Area Superfund Site 200-UP-1 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Richland, Washington. Available at: https://pdw.hanford.gov/document/0091413.

Gelhar, L.W., C. Welty, and K.R. Rehfeldt, 1992, "A critical review of data on field-scale dispersion in aquifers," *Water Resources Research* 28(7):1955–1974.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald, 2000, *MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*, Open-File Report 00-92, U.S. Geological Survey, Reston, Virginia. Available at: http://pubs.er.usgs.gov/usgspubs/ofr/ofr200092.

NAD83, 1991, *North American Datum of 1983*, as revised, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: https://www.ngs.noaa.gov/datums/horizontal/north-american-datum-1983.shtml.

OSWER Directive 9285.6-10, 2002, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, U.S. Environmental Protection Agency, Washington, D.C. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100CYCE.PDF?Dockey=P100CYCE.PDF.

PNNL-15239, 2005, *Carbon Tetrachloride and Chloroform Partition Coefficients Derived from Aqueous Desorption of Contaminated Hanford Sediments*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15239.pdf.

PNNL-18564, 2009, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-18564.pdf.

S-N/99205-103-REV1, 2008, *Phase 1 Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 99: Rainier Mesa/Shoshone Mountain, Nevada Test Site, NYE County, Nevada*, Rev. 1, Stoller-Navarro Joint Venture, Las Vegas, Nevada. Available at: https://www.osti.gov/servlets/purl/932406.

Zheng, C. and P.P. Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*, Contract Report SERDP-99-1, U.S. Army Engineer Research and Development Center, U.S. Army Corps of Engineers, Vicksburg, Mississippi. Available at: https://apps.dtic.mil/dtic/tr/fulltext/u2/a373474.pdf.

Attachment A

Software Installation and Checkout Form for MODFLOW and Related Codes Build 0008

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: MODFLOW and Related Codes　　Software Version No.: Bld 8

EXECUTABLE INFORMATION:

2. Executable Name (include path):

```
Following executable files in directory: [redacted]/bin

MD5 Signature (unique ID)          Executable File Name    Code
--------------------------------   ---------------------   --------------------------
2fade33e27978063a9a70ff8605e4c0c   mf2k-chprc08dpl.x       MODFLOW-2000 double precision
8b0b28c5e102e63df95de542d83d013b   mf2k-chprc08spl.x       MODFLOW-2000 single precision
80d670658425653bf5bcbb97ad2a2730   mf2k-mst-chprc08dpl.x   MODFLOW-2000-MST double precis.
d879defafdc5ad25be51a484d73ea65d   mf2k-mst-chprc08spl.x   MODFLOW-2000-MST single precis.
682f0b1e9fcd6ac0b885f52a7ddfe821   mfusg-chprc08dpl.x      MODFLOW-USG double precision
a8a861f6d453647b100d63f064ca6af2   mfusg-chprc08spl.x      MODFLOW-USG single precision
1be4b7d3fc81881ff0b97ff7e67bd3ff   mt3d-chprc08dpl.x       MT3DMS double precision
37ae3dcb3e56cd27e3e889a90d0ae7c1   mt3d-chprc08spl.x       MT3DMS single precision
1e468c4409ac913843ce783aabed819c   mt3d-mst-chprc08dpl.x   MT3DMS-MST double precision
2d0a8a4c480318763b6aaaa0f880348a   mt3d-mst-chprc08spl.x   MT3DMS-MST single precision
```

3. Executable Size (bytes): MD5 signatures above uniquely identify each executable file

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   INTERA Austin Linux(R) Cluster

5. Operating System (include version number):

   Linux head.cluster 2.6.32-358.11.1.el6.centos.plus.x86_64 #1 SMP Wed Jun 12 19:12:17 UTC 2013 x86 64 x86 64 x86 64 GNU/Linux

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   INTERA "OLIVE" Linux Cluster

7. Operating System (include version number):

   Linux olive 4.4.0-38-generic #57~14.04.1-Ubuntu SMP Tue Sep 6 17:20:43 UTC 2016 x86_64 x86 64 x86 64 GNU/Linux

8. Open Problem Report? ◉ No ○ Yes　　PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   [redacted]/MODFLOW/Build-8

10. Procedure(s):

    CHPRC-00259 Rev. 3, MODFLOW and Related Codes Software Test Plan

11. Libraries:

    N/A (static linking)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: MODFLOW and Related Codes   Software Version No.: Bld 8

12. Input Files:

Per CHPRC-00259 Rev. 3

13. Output Files:

Found in test subdirectories

14. Test Cases:

MF-ITC-1 (both standard and MST versions of MODFLOW); run both single & double precision
MT-ITC-1 run for single and double precision, multiple solvers

15. Test Case Results:

All pass.

16. Test Performed By: WE Nichols

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Approved; installation added to HISI entries for MODFLOW and MT3DMS.

Prepared By:

19. WILLIAM NICHOLS (Affiliate) Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2017.06.28 09:07:58 -07'00'	WE Nichols	
Software Owner (Signature)	Print	Date

20. Test Personnel:

	WE Nichols	
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	N/R (CHPRC-00258 Rev. 3)	
Software SME (Signature)	Print	Date

A-6005-149 (REV 0)